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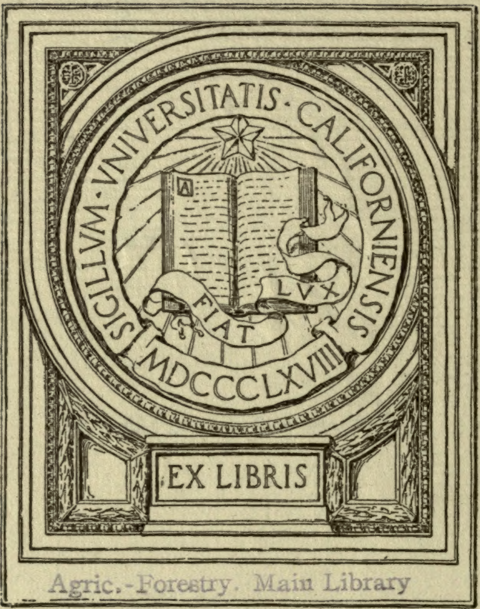

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No. 189

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
April 12, 1915.

STUDIES OF THE CODLING MOTH IN THE CENTRAL APPALACHIAN REGION.

By F. E. Brooks and E. B. Blakeslee,
Entomological Assistants, Deciduous Fruit Insect Investigations, Bureau of Entomology.

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INTRODUCTION.

In many localities throughout the central Appalachian region the recent rapid development of the apple-growing industry has made the control of the codling moth (*Carpocapsa pomonella* L.) a subject of special and increasing interest. The hilly or mountainous nature of the land has led to the location of orchards at elevations ranging from a few hundred feet to more than 4,000 feet above the level of the sea. The great diversity of temperature that occurs between the lower and the more elevated orchards has a marked effect on the time of transformation of the different stages of the codling moth, and consequently has direct bearing on the relative number and the destructiveness of second-brood larvæ.

In the spring of 1911 the Bureau of Entomology began a study of the codling moth in the region just mentioned, as a part of its inves-

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tigations of this insect throughout the United States, giving particular attention to time of appearance of the different broods at various altitudes and latitudes. The work was conducted by or under the immediate direction of the authors of this paper and was continued for three consecutive years at several points located in Virginia, West Virginia, and Maryland.

The writers are greatly indebted to the large number of fruit growers in the various localities where the investigations were carried on for the free use of orchards in which to obtain banding records, for buildings to shelter rearing jars, and for other courtesies. During the progress of the work many essential suggestions were made by Prof. A. L. Quaintance, in charge of Deciduous Fruit Insect Investigations, under whose direction the studies were made.

LOCALITIES IN WHICH INVESTIGATIONS WERE MADE.

The studies described herein were conducted at Charlottesville, Fishersville, Greenwood, and Winchester, Va.; Keyser, French Creek, and Pickens, W. Va.; and Hagerstown, Smithsburg, and Hancock, Md. The senior author had charge of the investigations in West Virginia and the junior author had charge in Virginia and Maryland. At several of the points mentioned only partial or incomplete records were obtained. The similarity of conditions at Smithsburg and Hancock, Md., and Keyser, W. Va., to other localities where records were being kept, together with a shortage of the fruit crop and the difficulty of visiting so many places at sufficiently frequent intervals, led to the discontinuance of operations at these points after the first year.

NATURE AND EXTENT OF THE INVESTIGATIONS.

The work was conducted by selecting, for banding, from 10 to 15 unsprayed bearing apple trees of late ripening varieties in each locality. Wherever it was possible medium-sized trees with smooth bark were chosen. In some cases such trees could not be found and old trees with rough bark were used. The rough scales of bark were scraped from the trunks and from the bases of the larger branches of these old trees, but even then they were much less desirable for the purpose than the younger, smooth-barked trees.

In the spring, before the first-brood codling-moth larvæ had commenced to leave the fruit, burlap bands were tied around the trunks of the trees 2 or 3 feet above the ground, and in some cases additional bands of the same material were placed around the bases of the larger branches. The trees were all tagged and an individual account kept as to the number of larvæ going under the bands to "spin up." The bands were removed and examined at frequent intervals and the larvæ taken from them were counted and placed in rearing jars. In 1911 the larvæ were collected and the rearing jars examined every 10 or 12 days, and in 1912 and 1913 the examinations were made every 3 or 4 days. During the course of the work more than 20,000 larvæ were collected and placed in the jars for rearing.

The jars containing the larvæ were supplied with small devices made of thin pieces of wood bound together, with openings between into which the larvæ entered to "spin up." It was found that strips cut from sheets of transparent celluloid could be used under the wood to advantage, as this permitted the wood covering to be removed for the purpose of examining the larvæ or pupæ without tearing or disarranging the cocoon. The jars were covered with cheesecloth and were placed under shelter, usually in open sheds, where they had out-of-door temperature. These sheds were always located near the orchard in which the larvæ had been collected. The jars were examined on the same dates as the bands, and the moths that had issued at each examination were counted and destroyed. Larvæ that wintered were preserved and records were made of the date they issued as moths the spring following. So far as possible the band records were checked and supplemented by observations on the condition of the insect in the orchard.

EXPLANATION OF THE USE OF TERMS.

The terminology of this paper is made to conform as nearly as possible with that of previous papers on the codling moth issued by the bureau. The term "generation" applies to the moth in all its stages from the egg to the adult, regardless of whether the life cycle is completed in one season or whether the insect winters during its development, in which case the life cycle would occupy parts of two seasons. The term "brood" is used to designate the insect in any of its four stages. Broods of eggs, larvæ, pupæ, and imagos occur normally, with more or less seasonal regularity, in the orchards of any given locality, and the term "brood" usually refers to the individuals in the aggregate of any particular stage of a given generation.

In the Appalachian section a first brood and a partial, or practically full, second brood of larvæ occur annually. In some southern localities a small third brood is possible. Some of the larvæ of the first brood and practically all those of the second brood winter in the cocoon. These are all spoken of as "wintering larvæ." In the spring these wintering larvæ transform to "spring pupæ," which in turn develop into "spring moths." The spring-brood moths produce "first-brood eggs," from which hatch "first-brood larvæ." The individuals of this generation that complete their transformation during the first season are known in their successive stages as "first-brood pupæ" and "first-brood moths." These moths in turn produce "second-brood eggs" and "second-brood larvæ." Where "second-brood pupæ" and "second-brood moths" occur they may produce "third-brood eggs" and "third-brood larvæ."

INVESTIGATIONS AT CHARLOTTESVILLE, VA.

DESCRIPTION OF LOCALITY.

Charlottesville is situated at the foot of the eastern slope of the Blue Ridge Mountains, at an elevation of 400 to 500 feet above sea level. In the immediate vicinity of the city there are several large and profitable bearing apple orchards, as well as a considerable acreage of young orchards planted within the last four or five years. Its own interests, therefore, as well as its proximity to the large orchards of the Blue Ridge section, make Charlottesville of considerable importance as a commercial apple-growing center. Investigations of the seasonal life history of the codling moth were carried on in this section in 1911, 1912, and 1913. Only the work of the last two years, however, was considered of sufficient value to be included in this report.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

A large proportion of the larvæ collected in the orchard in the fall of 1911 succumbed to cold or disease the following winter, and the rearing material available for moth emergence was consequently rather limited. On account of the small number of insects reared and some irregularity in the observations the records are not included in detail. Moths were first observed in the rearing cages at Charlottesville on May 7, and at Greenwood, where conditions are not far from those at Charlottesville, adults began appearing about May 8. Also the summer brood of moths emerged in the rearing cages at Charlottesville 45 days later (June 20), which is about the interval that must elapse between the two broods of adults in that latitude. Therefore we may safely assume that in 1912 the emergence of spring-brood moths began in the orchards at Charlottesville soon after May 1.

FIRST-BROOD MOTHS.

Table I gives the time of emergence of 247 moths that issued from band-collected material at Charlottesville in 1912. Beginning on June 20, emergence continued through the rest of June, the whole of July, and about half of August. One moth emerged as late as September 2.

TABLE I.—*Emergence of first-brood moths of the codling moth at Charlottesville, Va., in 1912.* (See fig. 1.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 20	1	Aug. 1	5
24	5	5	10
28	32	9	30
July 2	1	13	20
5	42	17	7
10	6	21	3
13	22	25	0
17	15	29	0
21	23	Sept. 2	1
25	12		
29	12	Total	247

BAND COLLECTIONS.

It would be difficult to find a more satisfactory orchard in which to conduct band-record experiments than the one used at Charlottesville in the summer of 1912. The trees used were part of an orchard that had not been sprayed for a number of years. Those banded were of the Winesap variety, about 18 years old, and carried a heavy crop of fruit throughout the season. In Table II are given the collections of the season and the summarized results of the rearing experiments.

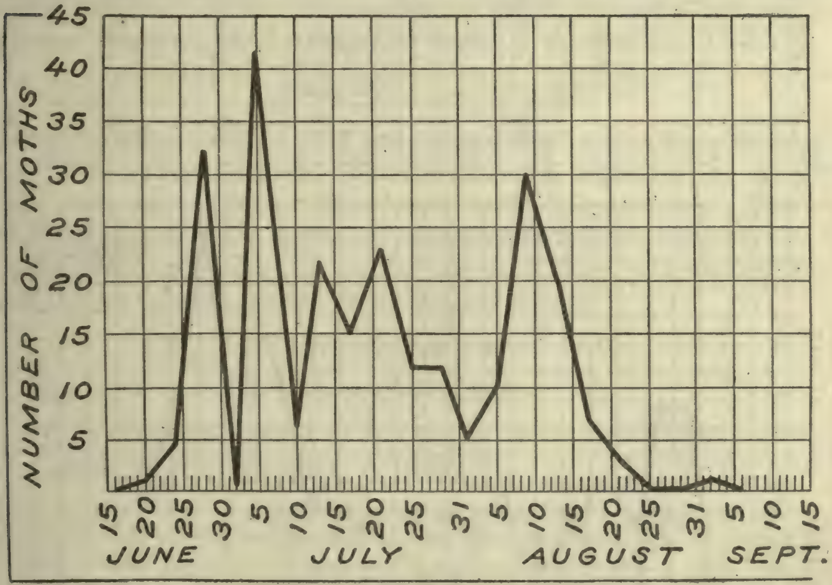

FIG. 1.—Diagram to illustrate emergence of first-brood moths of the codling moth (*Carpocapsa pomonella*) at Charlottesville, Va., in 1912.

TABLE II.—*Number of larvæ of the codling moth taken from the bands and reared at Charlottesville, Va., in the summer of 1912 and the spring of 1913.* (See fig. 2.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number of moths emerging, 1912.	Number over-wintering.	Number winter-killed.	Number of moths emerging, 1913.
June 12	12		12			
17	48	14	34			
22	49	11	38			
26	26	8	18			
July 1	34	11	21	2	2	
5	33	10	23			
9	26	9	17			
13	20	2	17	1		1
17	20	1	19			
21	34	12	22			
25	27	11	15	1		1
Aug. 1	12		4	8	2	6
5	20		5	15		15
10	23	1	1	21	2	19
13	26	3		23	3	20
17	27			27		27
21	37	10	1	26	16	10
25	30			30	15	15
29	45	10		35	15	20
Sept. 2	61	7		54	28	26
5	60	6		54	13	41
10	52	9		43		43
14	80	20		60	5	55
18	53	2		51	19	32
25	32	3		29	13	16
29	14	4		10	4	6
Oct. 2	2			2		2
5	2			2	2	
Total	905	164	247	494	139	335
Per cent	100	18.12	27.29	54.59	15.36	39.23

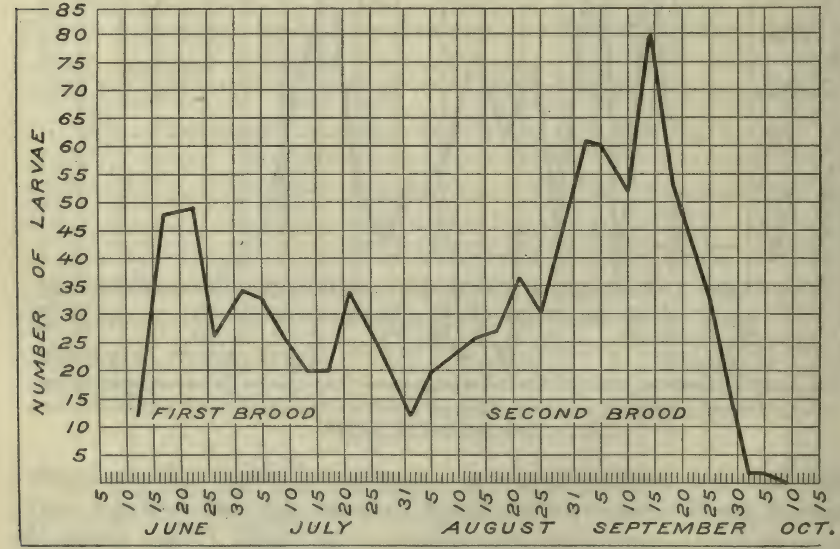

FIG. 2.—Diagram to illustrate band collections of larvæ of the codling moth at Charlottesville, Va., in 1912.

Unfortunately examinations were not begun until June 12, while larvæ were doubtless leaving the fruit as early as June 5–6. Codling-moth larvæ appeared under the bands in considerable number throughout June and July, most of those collected previous to August 1 transforming to adults the same season. After August 1 the number of larvæ collected again increased considerably, the greater part of those taken after this date spinning up and wintering. Since summer-brood moths appeared June 20, it is reasonable to suppose that second-brood larvæ were beginning to enter the apples about July 1. If we allow a slightly longer time than has been found by other observers to be the minimum feeding period of the second brood, we might expect second-brood larvæ to be leaving the fruit by the last of July to the first of August. The fruit was picked shortly after October 5 and the records discontinued, although a few of the second brood had not finished feeding by that time.

Table II gives the results of the rearing experiments carried on with the 905 larvæ taken in the orchard in the summer of 1912. Due to handling, cannibalism, disease, etc., 18.12 per cent were lost in the rearing jars; 27.29 per cent emerged as moths that season; 54.59 per cent wintered; 15.36 per cent were winter-killed; and 39.23 per cent passed the winter and emerged as moths in the spring of 1913.

SUMMARY FOR SEASON OF 1912.

At Charlottesville in 1912 the spring-brood moths began emerging in the early part of May. First-brood larvæ began leaving the fruit the early part of June. First-brood moths began emerging June 20, allowing 10 days for egg-laying and incubation; second-brood larvæ began feeding by July 1. After August 1 most of the larvæ taken under the bands belonged to the second brood.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

The emergence records of 355 moths of the spring brood at Charlottesville in 1913 are given in Table III.

TABLE III.—*Emergence of spring-brood moths of the codling moth at Charlottesville, Va., in 1913.* (See fig. 3.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
Apr. 18	2	May 21	21
21	2	24	21
24	2	27	11
27	7	30	10
30	18	June 2	8
May 3	78	5	8
6	27	8	1
9	42	11	1
12	17		
15	55	Total	355
18	24		

It will be remembered that the work of 1912 did not include a detailed account of the appearance of the spring brood. There was, however, very good evidence that spring-brood emergence began that season shortly after May 1. On the whole the seasonal conditions of the spring of 1913 were slightly in advance of those of 1912, and spring-brood moth emergence seems to have occurred about 10 days earlier in the former year. Moths began appearing in numbers on April 27–30, and maximum emergence was reached on May 3. Moths continued to issue in jars through May and part of June, emergence ceasing June 11. It is probable that first-brood larvæ began feeding by May 1, or 12 days after the first moth appeared in the rearing cages.

FIRST-BROOD MOTHS.

In 1913 the first of the first brood or summer brood of moths issued on June 14, from material taken under the bands in the orchard on June 5. However, emergence occurred in numbers on June 23 and reached its maximum on July 8. On the whole the graph in figure 3 probably represents fairly well the time of appearance in the orchard of the two broods of moths at Charlottesville in 1913. An occasional second-brood larva may have begun feeding by June 25, but it is probable that the insects were not entering the fruit in numbers before July 1.

TABLE IV.—*Emergence of first-brood moths of the codling moth at Charlottesville, Va., in 1913.* (See fig. 3.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 14	1	July 23	7
17	3	26	7
20	5	29	16
23	18	Aug. 1	7
26	11	4	2
30	24	7	2
July 2	26	10	0
5	26	13	3
8	40	16	1
11	21	19	0
14	28	22	1
17	10		
20	11	Total	270

BAND COLLECTIONS.

At Charlottesville, as in the other parts of the central Appalachian section, the short crop of fruit during the season of 1913 seriously interfered with the work. After the dropping, which normally follows the feeding of the first brood, not enough fruit remained to furnish food for the second-brood larvæ, and the unusually small numbers of larvæ that appeared under the bands in the latter part of the summer throw out of line completely the proportions of transforming and wintering insects. The relatively small number of overwintering larvæ given in Table V must be considered as unusual and not as evidence of what occurs under normal conditions.

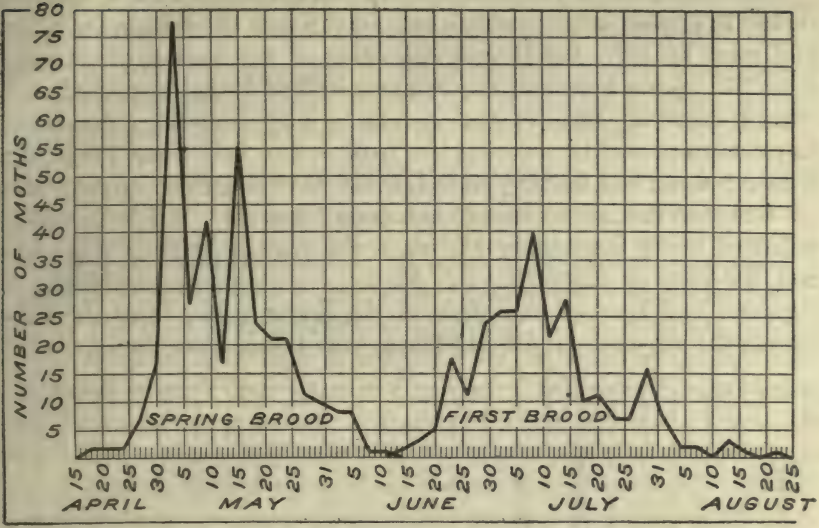

FIG. 3.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Charlottesville, Va., in 1913.

TABLE V.—*Number of larvæ of the codling moth taken from bands and reared at Charlottesville, Va., in 1913.* (See fig. 4.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number of moths emerging, 1913.	Number of larvæ over-wintering.
June 5	6	2	4	....
8	20	7	13	....
11	33	11	22	....
14	18	5	13	....
17	35	19	16	....
20	90	32	57	1
23	37	10	27	....
26	54	27	25	2
30	85	52	31	2
July 2	19	8	9	2
5	23	3	20	....
8	15	7	8	....
11	10	4	5	1
14	8	3	4	1
17	10	3	7	....
20	3	2	1	....
23	1	....	1	....
26	5	....	5	....
29	1	....	1	....
Aug. 1	2	1	....	1
4	13	10	....	3
7	3	....	....	3
10	1	1	....	....
13	8	3	1	4
16	3	1	....	2
19	6	1	....	5
22	3	1	....	2
25	2	....	....	2
28	9	5	....	4
Sept. 1	1	....	....	1
3	1	....	....	1
6	5	1	....	4
9	2	....	....	2
12	....	....	....	....
15	10	4	....	6
Total	542	223	270	49
Per cent	100	41.14	49.82	9.04

First-brood larvæ were taken from the bands on June 5, and continued to appear in increasing numbers through the remainder of June and most of July, the largest collection of the season occurring on June 20. Since moths of the summer or first brood appeared in the rearing cages on June 14 and in numbers by June 20, second-brood larvæ were probably entering the fruit in the field June 25–30, and, allowing a normal feeding period, must have begun to appear under the bands in the last of July to the first of August. A few larvæ were collected up to September 15, when the remaining fruit was picked and the records discontinued. Figure 4 represents graphically the numbers and time of collection of the larvæ taken from the bands during the season. In all, 542 larvæ were taken from the bands, 223, or 41.14 per cent, of which perished in the rearing cages; 49.82 per cent emerged as moths the same season, while 9.14 per cent spun up and wintered. As has already been explained, the comparative numbers of wintering and transforming larvæ given in Table V must not be considered usual. At Charlottesville in an ordinary season a large proportion of the first brood transforms, giving rise to a relatively large second brood, and with a fair crop of fruit the larvæ of the second brood taken under the bands should far exceed the first in numbers.

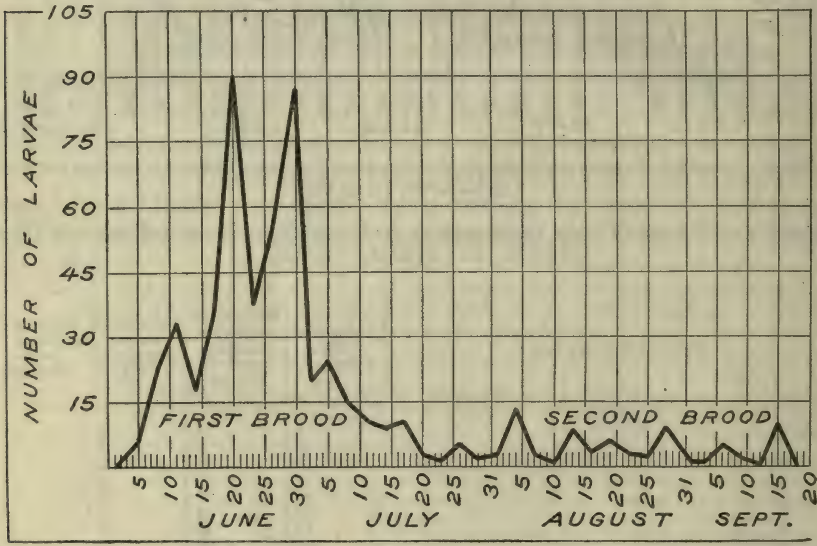

FIG. 4.—Diagram to illustrate band collections of larvæ of the codling moth at Charlottesville, Va., in 1913.

SUMMARY FOR SEASON OF 1913.

Spring-brood moths began emerging at Charlottesville on April 18. First-brood larvæ might be expected to have entered the fruit by April 28–30, though not in any number until several days later.

First-brood larvæ were taken under the bands June 5, and by August 1 probably most of them had left the fruit. First-brood moths appeared in the rearing cages on June 14, and in numbers June 23. Second-brood larvæ must have been entering fruit June 25–30, and were leaving by the last of July to the first of August.

INVESTIGATIONS AT GREENWOOD, VA.

DESCRIPTION OF LOCALITY.

Greenwood is situated about 18 miles west of Charlottesville, in a section of the Blue Ridge Mountains where commercial apple growing has been well established for years. In a mountain orchard section, such as this, there is considerable variation in the elevation of orchard sites. The orchard in which band-record experiments were conducted was at an altitude of about 900 feet above sea level. The work in this section for the season of 1912 is given in part only, the moth emergence of that summer being considered of sufficient importance to find a place in this report.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

Table VI contains the emergence records of 180 moths as they occurred in the rearing cages at Greenwood in 1912. The first visit of the season to Greenwood was made on May 8, and the table shows that three moths were found in the jar of wintering larvæ at that time; while these may have emerged two or three days previously, from the number appearing two days later (May 10) it can be assumed that moth emergence was just beginning on May 8.

TABLE VI.—*Emergence of spring-brood moths of the codling moth at Greenwood, Va., in 1912.* (See fig. 5.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 8	3	May 30	34
10	11	June 3	15
14	18	7	5
18	28		
22	20	Total	180
26	46		

Some time was spent in the orchard in an unsuccessful search for eggs and young larvæ, and their absence indicates that moths had at least not been appearing in the field in numbers up to that time. Maximum emergence did not occur until May 26, although moths were appearing in some numbers during all of the period from May 10 to June 3. None emerged in the rearing cages after June 7, although, had more insects been under observation, an occasional adult would probably have appeared later.

FIRST-BROOD MOTHS.

The first collection of larvæ in 1912 was delayed until June 12, though as none of those taken under the bands at the time had pupated, the beginning of first-brood moth emergence was not seriously affected thereby. In all 639 moths appeared in the rearing cages between June 23 and August 28. (See Table VII.)

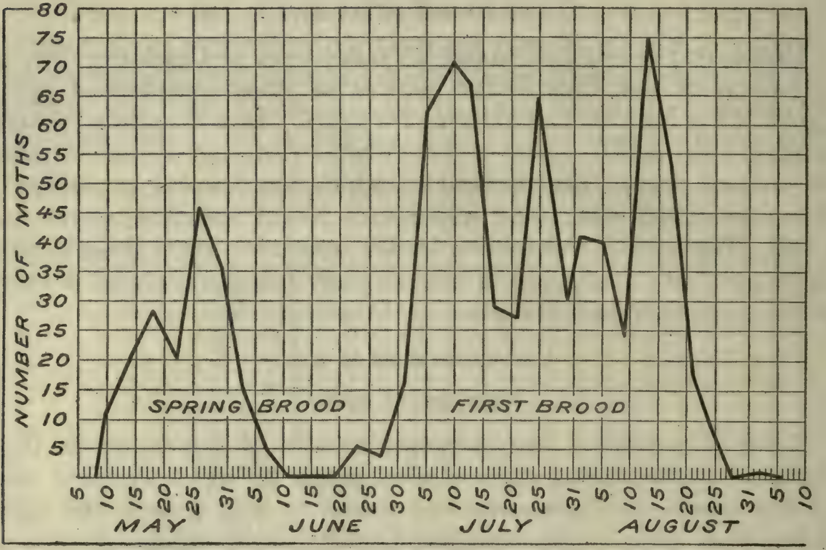

FIG. 5.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Greenwood, Va., in 1912.

TABLE VII.—*Emergence of first-brood moths of the codling moth at Greenwood, Va., in 1912.* (See fig. 5.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 23	6	Aug. 1	41
27	4	5	40
July 1	17	9	24
5	62	13	75
10	71	17	53
13	67	21	18
17	29	24	9
21	27	28	0
25	65		
29	30	Total	639

The seasonal appearance of the two broods of moths is given in figure 5.

Work at Greenwood was discontinued in 1913, the transformations of the codling moth being apparently so nearly the same as at Charlottesville that almost daily observation would be necessary to distinguish any variation at all, and according to the plan of work followed it was impossible to take records oftener than every three or four days.

INVESTIGATIONS AT HAGERSTOWN, MD.

DESCRIPTION OF LOCALITY.

Hagerstown, Md., is situated on a comparatively level portion of the lower Cumberland Valley. The country is more or less rolling, but the relative differences in altitude are not great, the actual elevation above sea level of most of this section being from 500 to 600 feet. There are a few large orchards in the vicinity, but fruit growing in a commercial way has not received much attention until recently. However, Hagerstown is not far from some very important fruit-growing districts on the east, the west, the north, and the south. Band-record experiments were carried on in this section for 1911, 1912, and 1913.

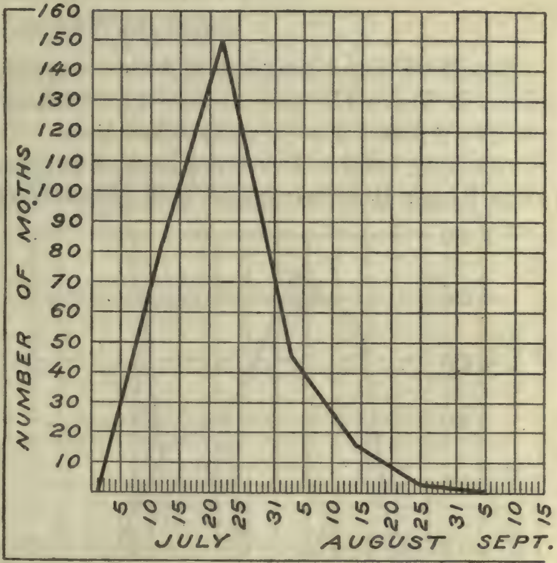

FIG. 6.—Diagram to illustrate emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1911.

INVESTIGATIONS IN 1911.

FIRST-BROOD MOTHS.

The long intervals between observations in 1911 (10 to 12 days) make the records of that year of rather doubtful value, and while they are included for Hagerstown and Pickens, it must not be understood that they are comparable in any but a general way to the data obtained in the two following years' work in these sections.

TABLE VIII.—*Emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1911.* (See fig. 6.)

Date of observation.	Number of moths emerging.
July 12	82
22	151
Aug. 3	46
14	16
Aug. 25	3
Total	298

The collection of larvæ from the bands, and the summer-brood moth emergence given in Table VIII, can be better appreciated by reference to figures 6 and 7, and it is doubtful if much could be added by a detailed discussion of the season's work.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

It will be noted that the records for spring-brood moth emergence given in Table IX were obtained at Smithsburg, Md., and therefore do not represent accurately what took place at Hagerstown. The Smithsburg section is 9 miles east of Hagerstown, at the foot of the Blue Ridge Mountains, and at a considerably higher elevation, and the seasonal conditions at Hagerstown are somewhat in advance of those at Smithsburg. However, no satisfactory record of moth emergence was obtained at Hagerstown in the spring of 1912, and as this was practically the only record of any value secured at Smithsburg, it is included in the report of the work in the former section.

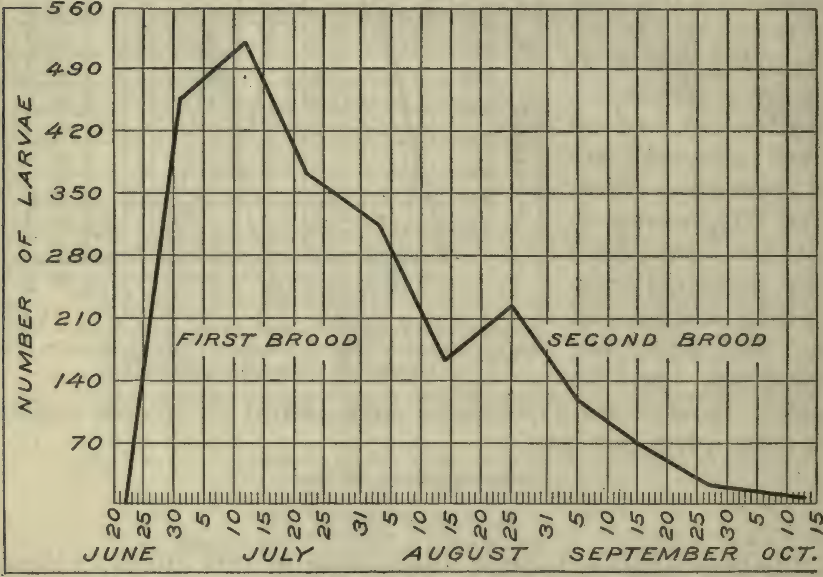

FIG. 7.—Diagram to illustrate band collections of larvæ of the codling moth at Hagerstown, Md., in 1911.

TABLE IX.—*Emergence of spring-brood moths of the codling moth at Smithsburg, Md., in 1912.* (See fig. 8.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 30	2	June 19	10
June 3	9	23	4
7	17	Total	85
11	23		
15	20		

It will be seen from figure 8 that emergence began on May 30, and reached its maximum on June 11, after which time the moths decreased in numbers, ceasing to appear altogether after June 23. It would probably be safe to say that the first-brood larvæ were entering fruit by June 1, or very soon thereafter.

FIRST-BROOD MOTHS.

The emergence records of 148 moths given in Table X were obtained from the material collected in the orchard at Hagerstown and represent fairly well the occurrence of the summer or first brood of moths in the field. The 148 moths accounted for in this table comprise all that transformed during that season of the 1,706 larvæ reared, a fact which probably accounts for the relatively small number of second-brood larvæ that appeared under the bands later in the summer (see fig. 9).

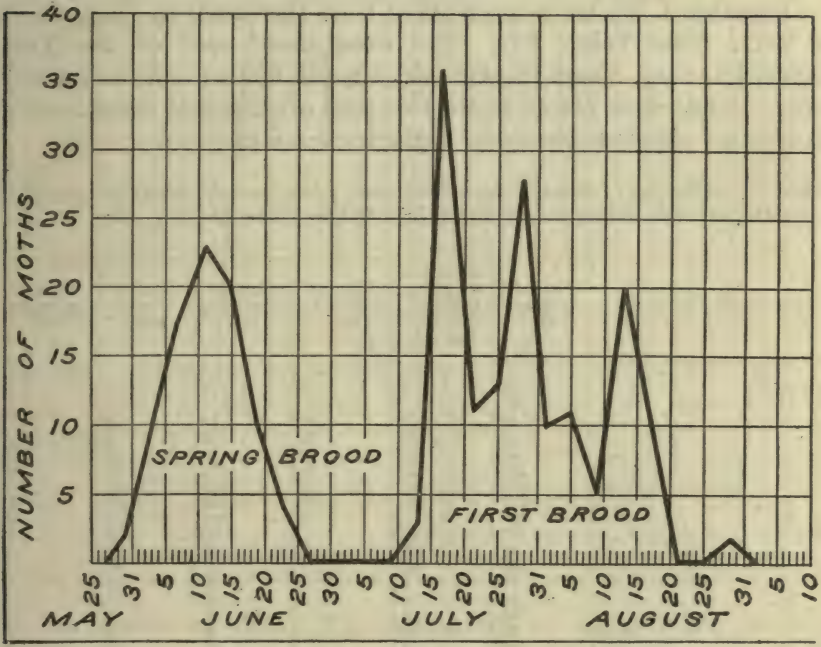

FIG. 8.—Diagram to illustrate emergence of spring-brood moths of the codling moth at Smithsburg, Md., and first-brood moths at Hagerstown, Md., in 1912.

TABLE X.—*Emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1912.* (See fig. 8.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 13	3	Aug. 13	20
17	36	17	9
21	11	21	
25	13	25	
29	28	29	2
Aug. 1	10		
5	11	Total	148
9	5		

First-brood moths began to emerge on July 13, and emergence continued throughout the remainder of July and the fore part of August. Two adults appeared as late as August 29, though emergence had practically ceased August 17. The codling moth is very sensitive to weather conditions, its development being especially retarded by cold, and the irregularity in the emergence curve of first-brood moths in figure 8 is due, in part at least, to extreme temperature variations of the season.

Second-brood larvæ probably began entering fruit at Hagerstown in 1912, about July 23 to 27.

BAND COLLECTIONS.

Altogether 1,706 larvæ were taken from the bands at Hagerstown in 1912. (See Table XI.) The trees used were of the York Imperial variety, about 15 years old, smooth bodied and loaded with fruit. Bands were placed in the fore part of June and examinations made every three or four days, beginning June 15.

TABLE XI.—*Number of larvæ of the codling moth taken from the bands and reared at Hagerstown, Md., during the summer of 1912 and the spring of 1913.* (See fig. 9.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number emerged, 1912.	Number overwintering.	Number winter-killed.	Number emerged, 1913.
June 29	11	4	7			
July 1						
5	58		42	16	7	9
9	55	24	28	3	3	
13	144	27	42	75	24	51
17	240	53	15	172	109	63
21	183	44	2	137	137	
25	207	61	10	136	100	36
29	228	75	2	151	112	39
Aug. 1	117	22		95	40	55
5	97	18		79	25	54
9	59	12		47	36	11
13	35	5		30	23	7
17	30	2		28	11	17
21	15	10		5		5
25	60	31		29	19	10
30	30	8		22	2	20
Sept. 2	48	22		26	19	7
6	16	9		7	7	
10	21	7		14	7	7
14	16	4		12	8	4
18	28	8		20	13	7
22	8	2		6	4	2
Total	1,706	448	148	1,110	706	404
Per cent	100	26.26	8.68	65.06	41.38	23.68

From figure 9 it will be seen that the first larvæ appeared under the bands on June 29, the numbers gradually increasing through July. From August 1 to 21 the collections decreased, increasing again slightly after the latter date, and it is probable that second-brood larvæ were beginning to leave the apples about this time. Only 8.68 per cent of the first-brood larvæ transformed to moths, which explains the relatively small second brood of larvæ shown in figure 9.

Comparison of figures 7 and 9 would suggest that, in the relative numbers of the two broods of larvæ appearing under the bands, the seasons of 1911 and 1912 were very similar.

As has already been said, only 8.68 per cent of the 1,706 larvæ taken under the bands at Hagerstown in 1912 transformed to moths that summer. The percentage of 26.26 that died in the rearing cages from handling, cannibalism, disease, immaturity, and other causes compares closely with that observed at other points, and the rearing work was evidently done with as much care and under as favorable conditions as in the localities where a much larger proportion of the first brood transformed; 65.06 per cent wintered, 41.38 per cent were winter-killed, and 23.68 per cent emerged as moths in the spring of 1913. The percentage of winter-killed larvæ at Hagerstown was much larger than in other localities that year.

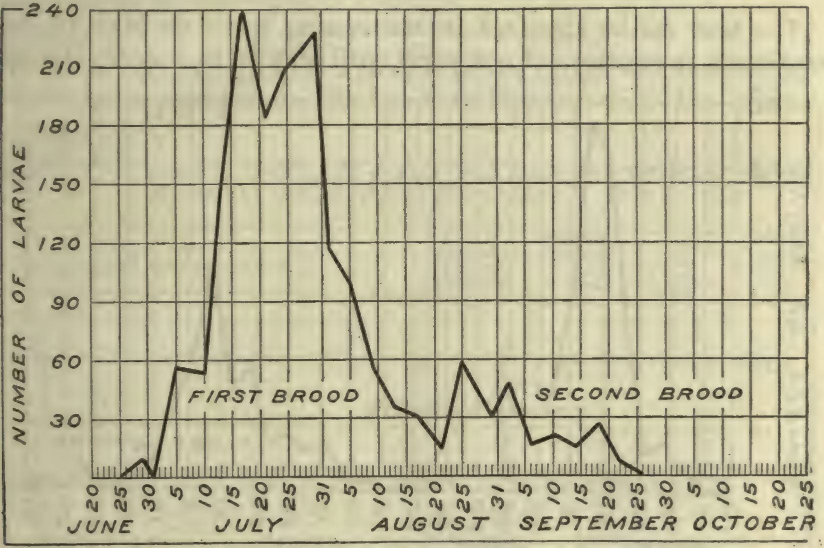

FIG. 9.—Diagram to illustrate band collections of larvæ of the codling moth at Hagerstown, Md., in 1912.

SUMMARY FOR SEASON OF 1912.

Spring-brood moths began emerging in rearing cages at Smithsburg, Md., on May 30 (probably several days later than at Hagerstown). First-brood larvæ were probably entering fruit 10 to 12 days later (soon after June 1, at Hagerstown). First-brood larvæ were leaving apples in the field from June 25 to 29 to August 17 to 21.

First-brood moths began emerging from field-collected material on July 13. Second-brood larvæ probably began feeding soon after July 23, and were leaving the fruit in numbers soon after August 21.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

Table XII gives the emergence of moths of the spring brood at Hagerstown in 1913.

TABLE XII.—*Emergence of spring-brood moths of the codling moth at Hagerstown, Md., in 1913.* (See fig. 10.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 15	2	June 5	45
18	6	8	22
21	12	11	25
24	9	27	81
27	38		
30	77	Total	404
June 2	87		

The first moths appeared in the rearing cages on May 15, but maximum emergence did not occur until May 30 to June 2. Careful records were taken every three days up to and including June 11, but from June 11 to June 27 observations were discontinued, as indicated by the dotted line in figure 10. However, of 404 moths accounted for in Table XII, all but 81 had emerged by June 11, and the break from then until June 27 does not seriously affect the value of the records. Allowing 10 to 12 days for egg laying and incubation, first-brood larvæ were evidently beginning to feed by May 25 to 27.

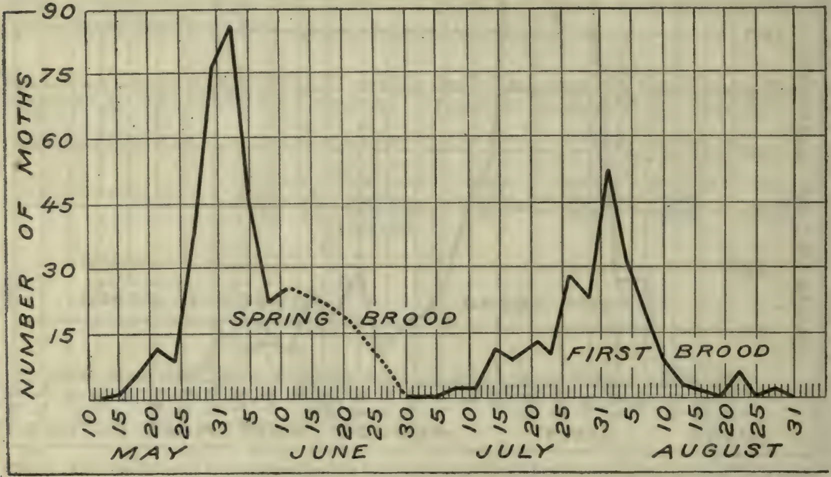

FIG. 10.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Hagerstown, Md., in 1913.

FIRST-BROOD MOTHS.

The relation of the two broods of moths emerging at Hagerstown in 1913 is clearly illustrated in figure 10. Adults appeared in the rearing jars with more or less regularity from July 8 to August 10. Emergence ceased altogether on August 28. (See also Table XIII.)

TABLE XIII.—*Emergence of first-brood moths of the codling moth at Hagerstown, Md., in 1913.* (See fig. 10.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 8	2	Aug. 7	20
11	2	10	8
14	11	13	3
17	8	16	1
21	13	19	0
23	10	22	6
26	29	25	0
29	23	28	2
Aug. 1	53		
4	31	Total	222

Probably a few second-brood larvæ were entering fruit in the field by July 20 to 25.

BAND COLLECTIONS.

In Table XIV are given the records of the collections and rearings of 2,756 larvæ taken under the bands at Hagerstown in the summer of 1913.

TABLE XIV.—*Number of larvæ of the codling moth taken from bands and reared at Hagerstown, Md., during the summer of 1913.* (See fig. 11.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Number of moths emerging, 1913.	Number overwintering.
June 27	3	1	2	
30	12	4	8	
July 2	38	12	17	9
5	30	6	18	6
8	78	19	24	35
11	86	31	34	21
14	136	38	41	57
17	95	22	24	49
21	181	53	28	100
23	116	22	14	80
26	150	77	7	66
29	108	44	4	60
Aug. 1	105	40		65
4	73	11	1	61
7	109	36	3	70
10	108	27	1	80
13	101	11		90
16	148	49	1	98
19	121	41		80
22	110	28		82
25	26	6		20
28	128	[1] 104		24
31	92	16		76
Sept. 3	203	48		155
6	111	34		77
9	127	61		66
12	42	8		34
15	32	12		20
18	14	4		10
21	18	8		10
25	9	5		4
27	17	1		16
30	9	3		6
Oct. 3	5			5
6	5	1		4
9	6			6
12	2			2
15	1			1
18	1			1
Total	2,756	883	227	1,646
Per cent	100	32.04	8.24	59.72

[1] Eaten by mice.

Larvæ began to appear on June 27, and were taken under the bands in numbers through the remainder of June, all of July, and part of August. It will be noticed that on August 25 (fig. 11) there was a sharp decrease in the number of insects collected. Considering the time first-brood moths began appearing in the rearing cages at Hagerstown, and correlating with what was taking place at Winchester and elsewhere, second-brood larvæ very likely began appearing under the bands soon after August 25, though an unusual overlapping of the two broods of larvæ is apparent in the collections. Records were discontinued about October 25, though no larvæ appeared under the bands later than October 18.

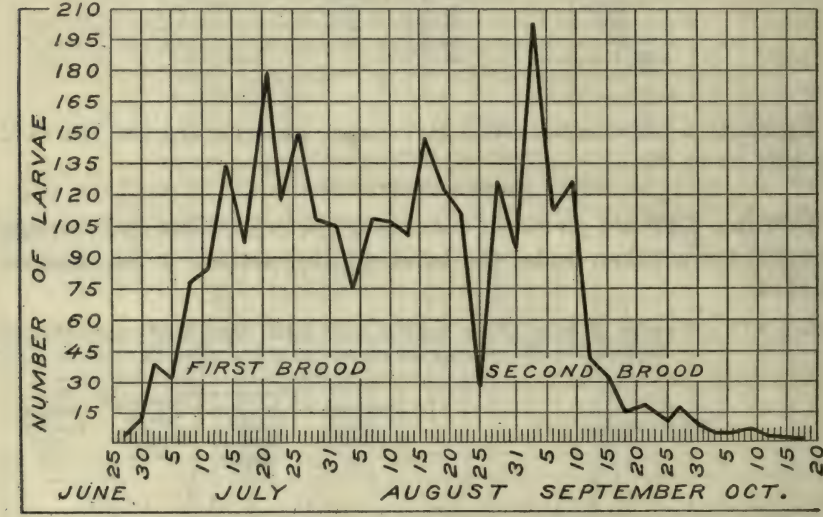

FIG. 11.—Diagram to illustrate band collections of larvæ of the codling moth at Hagerstown, Md., in 1913.

The 8.24 per cent of transforming larvæ taken under the bands at Hagerstown in 1913 compares closely with the 8.68 per cent that transformed in 1912. The 32.04 per cent of larvæ that died from handling, cannibalism, etc., in 1913 is much higher than has usually been observed, due in part to the fact that one jar of larvæ was devoured by mice, and discarding consideration of this cage the loss is brought down to 29.37 per cent. The 59.72 per cent of wintering larvæ is only slightly less than the 65.06 per cent obtained in 1912.

SUMMARY FOR SEASON OF 1913.

Spring-brood moth emergence began May 15 and closed June 27. Allowing 10 to 12 days from emergence to hatching of first eggs, we might expect that first-brood larvæ began entering the apples May 25 to 27. First-brood larvæ appeared under the bands on June 27. First-brood moths began to emerge in the rearing cages on July 8, though not in numbers until July 11 to 14. Second-brood larvæ were probably beginning to enter the fruit about July 20 to 25 and were leaving in numbers after August 25.

INVESTIGATIONS AT WINCHESTER, VA.

DESCRIPTION OF LOCALITY.

Winchester, the county seat of Frederick County, Va., is one of the principal shipping points for a large and well-developed apple-producing territory in the northern part of the Shenandoah Valley. The altitude of most of the country immediately surrounding Winchester varies from 650 to 800 feet above sea level; thus the relative variations in elevation are not great and the seasonal conditions are fairly uniform for the whole section. The life-history studies of the codling moth in this section for the seasons of 1912 and 1913 follow.

In Table XV are included the emergence records of 94 moths that issued at Winchester in the spring of 1912.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

TABLE XV.—*Emergence of spring-brood moths of the codling moth at Winchester, Va., in 1912.* (See fig. 12.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 22	2	June 11	8
26	4	15	4
30	19	19	1
June 3	26	23	3
7	26	27	1
		Total	94

The first moth appeared in the laboratory rearing cages between May 18 and 22, though observations indicate that moths emerged several days earlier in the field. On the 24th of May eggs were rather common in the orchard, and two newly hatched larvæ were found just entering apples. Certainly moths were emerging in the field, in 1912, not later than May 15. By May 30 first-brood larvæ were observed entering fruit in the orchard in considerable numbers. The last spring-brood moth emerged June 27.

The fruit was unusually large when attacked by the codling moth in 1912, and it is of some interest to note that curculio cuts and rough spots on the apples were more frequently used by the first-brood larvæ as points of entrance than was the calyx end of the fruit.

The first of the 1912 summer or first-brood moths emerged on July 9. Eggs were laid by moths in confinement on July 13, by moths emerging during the period from July 9 to 13, but since one moth issued

July 9 it is possible oviposition began two or three days earlier in the field. Moths emerged in the rearing cages until August 21. (See Table XVI.)

FIRST-BROOD MOTHS.

TABLE XVI.—*Emergence of first-brood moths of the codling moth at Winchester, Va., in 1912.* (See fig. 12.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 9	1	Aug. 2	25
13	20	6	8
17	25	10	23
20	27	14	18
25	27	18	13
29	33	21	8
		Total	228

The relation of the two broods of moths can be better understood by reference to figure 12, where their seasonal appearance is represented graphically.

BAND COLLECTIONS.

An old unsprayed orchard located about a mile south of Winchester was used for the band-record experiments of 1912. The trees were of late fall and winter varieties well laden with fruit, and the infestation was very extensive, practically every apple being attacked by one or more codling-moth larvæ at some time during the season.

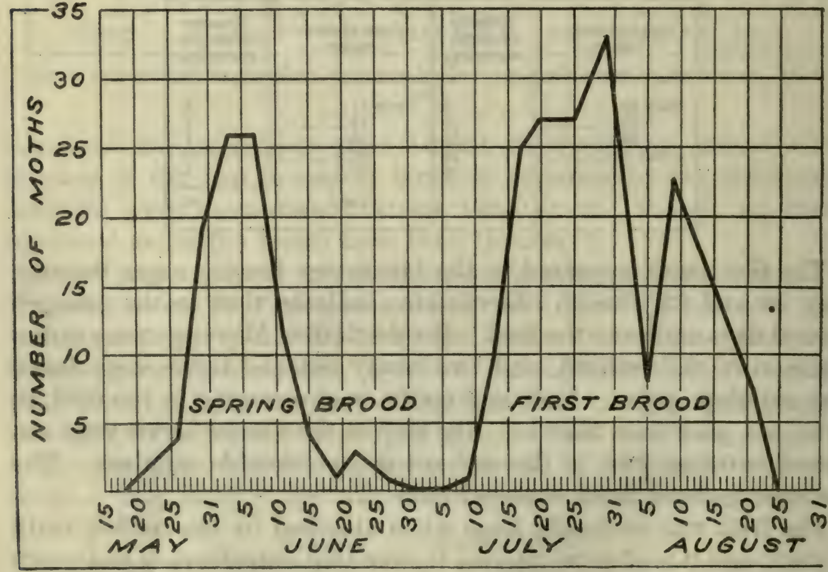

FIG. 12.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Winchester, Va., in 1912.

One larva was taken under the bands on June 19. The number collected increased throughout the remainder of June and the first half of July. By referring to figure 13 it will be noticed that during the fore part of August there occurred a series of very small collections, and about this time evidently most of the first-brood larvæ had left the fruit, while those of the second brood were still feeding. On July 15 newly hatched larvæ were observed entering fruit in the field in sufficient numbers to exclude the probability of their belonging to the first brood, especially since the last of the spring-brood moths appeared on June 27. The second-brood larvæ did not hatch in the laboratory until July 19, but this was probably three or four days behind field conditions. Allowing for a normal feeding period, some of the second-brood larvæ should have been leaving the apples about August 9 to 13. The collections increased through the latter part of August and the first half of September. No larvæ appeared under the bands after October 18.

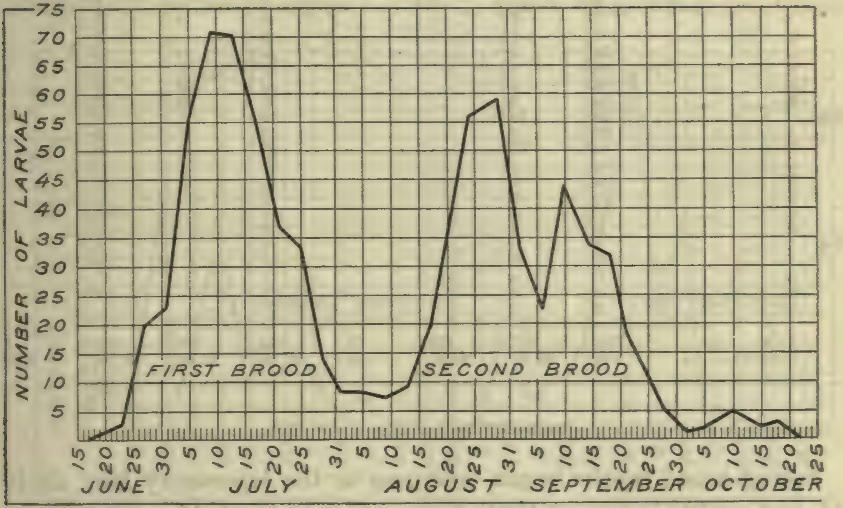

Fig. 13.—Diagram to illustrate band collections of larvæ of the codling moth at Winchester, Va., in 1912.

During the season of 1912 at Winchester 798 larvæ were taken from the bands and reared. Of these 27.19 per cent were killed in handling or were devoured by their fellows after being placed in the rearing cages; 28.57 per cent emerged as moths of the first brood; 1.38 per cent were parasitized; 42.86 per cent of the larvæ collected wintered, and 15.04 per cent were winter killed; 27.44 per cent passed the winter successfully and emerged the following season, while 0.38 per cent represents the proportion of parasites that issued in the spring of 1913. (See Table XVII.)

TABLE XVII.—*Number of larvæ of the codling moth taken from the bands and reared at Winchester, Va., during the summer of 1912 and the spring of 1913.* (See fig. 13.)

Date of collection, 1912.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Emerged, 1912.		Number of larvæ overwintering.	Number of larvæ winter-killed.	Emerged, 1913.	
			Moths.	Parasites.			Moths.	Parasites.
June 19	1		1					
23	3		3					
27	20	5	14		1	1		
July 1	23		23					
5	56	16	36	3	1	1		
9	71	24	42	4	1		1	
13	70	31	37	1	1		1	
17	56	16	31	3	6	2	4	
21	37	11	19		7	1	6	
25	33	17	11		5	1	4	
29	14	2	6		6		6	
Aug. 1	8	1	4		3		3	
5	8		1		7		7	
9	7	1			6	2	4	
13	9	1			8		8	
17	19	5			14	4	10	
21	37	7			30	8	21	1
24	56	4			52	19	33	
29	59	3			56	29	27	
Sept. 2	32	14			18	6	10	2
6	22	6			16	7	9	
10	44	17			27	15	12	
14	34	3			31	14	17	
18	32	6			26	10	16	
21	18	10			8		8	
25	11	6			5		5	
28	5	2			3		3	
Oct. 2	1				1		1	
5	2	1			1		1	
10	5	4			1		1	
15	2	1			1		1	
18	3	3						
Total	798	217	228	11	342	120	219	3
Per cent	100	27.19	28.57	1.38	42.86	15.04	27.44	0.38

SUMMARY FOR SEASON OF 1912.

Spring-brood moths began emerging in the laboratory May 18 to 22, and probably two or three days earlier in the field. First-brood larvæ began entering the fruit in the field May 24. First-brood larvæ began leaving the apples June 19. First-brood moths began emerging July 9; second-brood larvæ were observed entering fruit in the field on July 15, and a few had finished feeding by August 9 to 13.

INVESTIGATIONS IN 1913.

SPRING-BROOD AND FIRST-BROOD MOTHS.

The seasonal conditions of the spring of 1913 were considerably in advance of those of 1912, and the appearance of the spring-brood moths was correspondingly earlier. Moths appeared in numbers on May 6 and maximum emergence occurred three days later.

TABLE XVIII.—*Emergence of spring-brood moths of the codling moth at Winchester, Va., in 1913.* (See fig. 14.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 6	18	June 2	14
9	38	5	10
12	6	8	6
15	16	11	3
18	30	14	7
21	29	17	3
24	8	20	1
27	16		
30	14	Total	219

Moths continued to issue in the rearing cages until June 20. The irregularity of the emergence curve in figure 14 is due in most cases to fluctuations in temperature. The first moth emergence in confinement occurred 16 days earlier in 1913 than in 1912, but since adults were probably appearing in the field in 1912 not later than May 15, we may assume that spring-brood emergence began in the field only 10 to 12 days earlier in 1913.

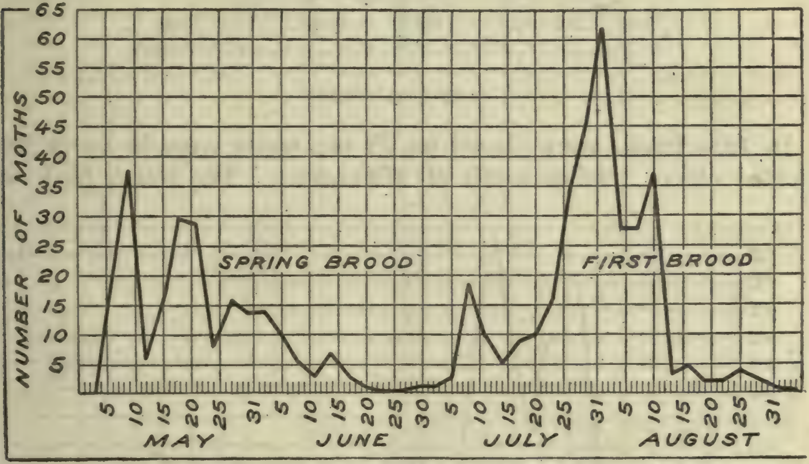

FIG. 14.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Winchester, Va., in 1913.

The seasonal appearance of the two broods of moths can perhaps be best appreciated by referring to figure 14. The emergence of 326 moths of the first brood are given in Table XIX. The first adults of this brood appeared in the laboratory in 1913 on June 30, nine days earlier than in 1912. However, not until July 5 to 8 did adults appear in any numbers, and in reality the difference in the time of appearance of summer, or first-brood, moths in the two seasons is very slight. Maximum emergence was not attained until one month later, or about August 1. The last of the first-brood moths emerged in the rearing cages on September 1.

TABLE XIX.—*Emergence of first-brood moths of the codling moth at Winchester, Va., in 1913.* (See fig. 14.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 30	1	Aug. 4	28
July 2	1	7	28
5	3	10	37
8	19	13	3
11	10	16	5
14	5	19	2
17	9	22	2
20	10	25	4
23	16	29	2
26	33	Sept. 1	1
29	45		
Aug. 1	62	Total	326

BAND COLLECTIONS.

In 1913 bands were placed on 12 old apple trees in an orchard located about 2 miles south of Winchester. The rough bark was scraped down and other hiding places of the insect destroyed, and on the whole probably most of the larvæ that left the fruit during the season found their way under the bands. The record of collections is given in Table XX.

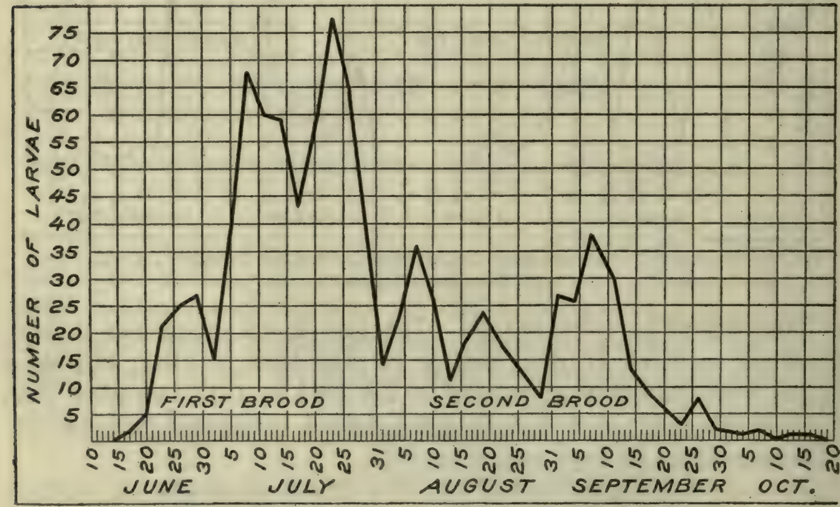

FIG. 15.—Diagram to illustrate band collections of larvæ of the codling moth at Winchester, Va., in 1913.

TABLE XX.—*Record of codling-moth larvæ taken from the bands and reared at Winchester, Va., in 1913.* (See fig. 15.)

Date of collection.	Number of larvæ collected.	Number of dead from handling, cannibalism, etc.	Emerged, 1913.		Number overwintering.
			Moths.	Parasites.	
June 17	2		2		
20	5	3	2		
23	22	4	14	4	
26	25	9	16		
29	27	5	15	7	
July 2	15	6	9		
5	38	23	15		
8	68	14	40	13	1
11	60	8	47		5
14	59	19	31	2	7
17	43	8	24	5	6
20	57	6	31	8	12
23	84	9	38	11	26
26	63	3	22	12	26
29	38	14	8	3	13
Aug. 1	14	7	3		4
4	23	6	3		14
7	36	11	3		22
10	26	9	2		15
13	11	6	1		4
16	19	9			10
19	24	9			15
22	18	9			9
25	14	5			9
29	8	2			6
Sept. 1	27	16			11
4	26	7			19
7	38	7			31
11	30				30
14	13				13
17	9				9
20	6				6
23	3				3
26	8				8
29	5				5
Oct. 1	2				2
4	1				1
7	2				2
10					
13	1				1
16	1				1
Total	971	234	326	65	346
Per cent	100	24.10	33.57	6.70	35.63

Careful examination of the bands was made, beginning about June 1, but no larvæ were taken until June 17, only two days earlier than in 1912, in spite of the fact that the first of the spring-brood moths were probably 10 to 15 days earlier than in the former season. From June 17 the collections increased until about August 1, when the numbers of insects collected decreased slightly, the proportion of those wintering increasing, and probably by August 7 to 10 most of the larvæ taken were of the second brood. The fact that the second brood did not equal the first in numbers and were somewhat irregular in their appearance under the bands is explained by the short fruit crop of the year.

Altogether 971 larvæ were collected and reared. Of this number 24.10 per cent were killed by handling, cannibalism, etc., the loss from this source being about the same as the 27.19 per cent that died from similar causes in 1912; 33.57 per cent were transformed to first-brood moths and 6.70 per cent were parasitized. The light fruit crop already noted reduced the number of wintering larvæ to 35.63 per cent.

SUMMARY FOR SEASON OF 1913.

Spring-brood moths began to emerge May 6, and a few first-brood larvæ were probably entering the fruit by May 16. First-brood larvæ began to appear under the bands in the orchard June 17, and from these larvæ a few first-brood moths emerged in the laboratory on June 30. Second-brood larvæ were probably entering fruit in numbers by July 15; they began leaving fruit about August 13.

INVESTIGATIONS AT FISHERSVILLE, VA.

DESCRIPTION OF LOCALITY.

Fishersville is the shipping point for a part of the Shenandoah Valley, in which commercial fruit growing has for years been of considerable importance. While in approximately the same latitude as Charlottesville, the seasonal conditions of this section are decidedly different chiefly on account of the much higher altitude; in fact, there is a much greater similarity of conditions between Fishersville and Winchester, both of which are in the Shenandoah Valley, than between Fishersville and Charlottesville, between which two points the Blue Ridge Mountains intervene. Differences in humidity and other climatic conditions occur between these two regions that may effect the development of the codling moth and that may not be entirely accounted for by differences in altitude. The band-record experiments were carried on in locations 1,400 to 1,500 feet above sea level, which is probably about the average elevation of orchards in this section.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

In a limited way the emergence dates of 119 moths given in Table XXI probably represent fairly well the occurrence of the spring brood at Fishersville in 1912. The rearing material was collected from the bands in the fall of 1911.

TABLE XXI.—*Emergence of spring-brood moths of the codling moth at Fishersville, Va., in 1912.* (See fig. 16.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 18	5	June 15	1
22	13	19	....
26	14	23	....
30	42	27	1
June 3	27	Total	119
7	5		
11	11		

Emergence began on May 18 and reached its highest numbers on May 30, 12 days later. However, since first-brood larvæ appeared under the bands on June 11, it is probable that moths emerged in the field several days prior to May 18. The moths continued to emerge through the remainder of May and in lessening number through the most of June, ceasing to appear altogether after June 27.

The records of the appearance of 273 moths of the first brood that issued from band-collected material at Fishersville in the summer of 1912 are given in Table XXII.

FIRST-BROOD MOTHS.

TABLE XXII.—*Emergence of first-brood moths of the codling moth at Fishersville, Va., in 1912.* (See fig. 16.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 2	5	Aug. 1	15
5	7	5	13
9	35	9	16
13	30	13	1
17	55	17	3
21	35	21	1
25	31		
29	26	Total	273

The work at Fishersville in 1912 was carried on under very ideal conditions, and July 2, the time when the first-brood moths began emerging in the rearing cages, represents field conditions as nearly as is possible with band-collected rearing material. The time of first appearance for the first-brood moths was seven days in advance of Winchester, while between the first emergence of spring-brood moths there was a four-day difference in the two sections.

Moths appeared in numbers through July and the first half of August, attaining their maximum on July 17. The last moth appeared in the rearing cages on August 21. The relative time of appearance of the two broods of moths at Fishersville in 1912 is shown in figure 16.

BAND COLLECTIONS.

About 12 smooth-bodied young York Imperial and Ben Davis apple trees were banded at Fishersville in 1912. On the whole the records given in Table XXIII and figure 17 represent fairly well the time the two broods of larvæ were leaving the fruit that season. Three larvæ were taken under the bands on July 11 and the number increased in the succeeding collections until about July 1, when the number gradually decreased until the fore part of August. By August 1 a large part of the first brood had left the fruit, as is evidenced in the band-record curve of figure 17.

Since first-brood moths emerged in the rearing cages on July 2, larvæ hatching from eggs laid by these moths might reasonably be expected to begin feeding by July 12 to 15. After August 9 the collections increased to the middle of September. Second-brood larvæ continued to appear under the bands until November 1, when the fruit was picked and the records discontinued.

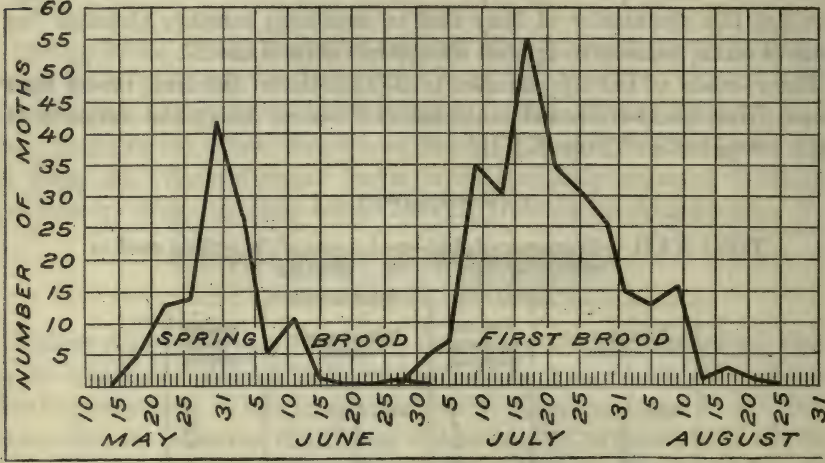

FIG. 16.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at Fishersville, Va., in 1912.

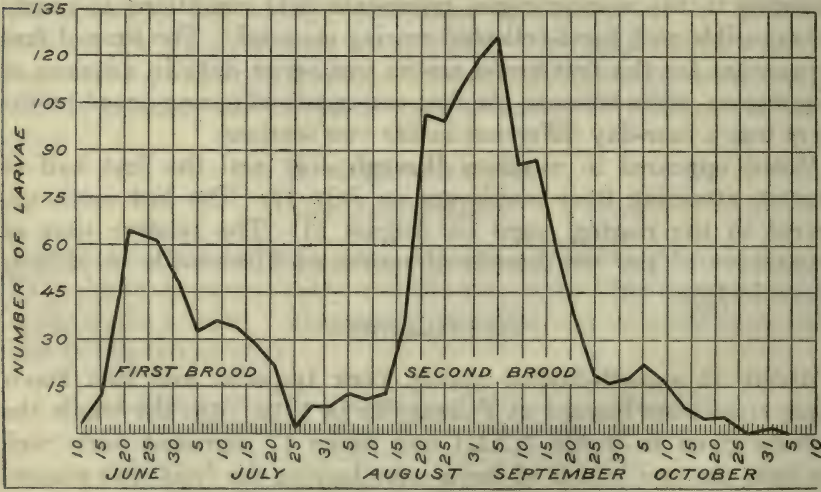

FIG. 17.—Diagram to illustrate band collections of larvæ of the codling moth at Fishersville, Va., in 1912.

In Table XXIII are recorded the numbers of larvæ taken in the orchard at different dates through the season. Altogether 1,418 larvæ were collected and reared, of which 12.90 per cent were killed by handling or devoured by their fellows in the rearing cages; 19.96 per cent emerged as adults during the summer of 1912; 67.14 per cent wintered and 24.19 per cent were winter killed; and 42.95 per cent emerged as moths in the spring of 1913.

TABLE XXIII.—*Number of larvæ of the codling moth taken from the bands and reared at Fishersville, Va., during the summer of 1912 and the spring of 1913.* (See fig. 17.)

Date of collecting larvæ.	Number of larvæ collected.	Number of dead from cannibalism, etc.	Number of moths emerging, 1912.	Number of larvæ overwintering.	Number of larvæ winter killed.	Number of moths emerging, 1913.
June 11	3	1	2	....	....	....
15	12	3	9	....	....	....
19	43	13	30	....	....	....
21	64	41	23	....	....	....
27	61	11	50	....	....	....
July 1	48	14	34	....	....	....
5	32	5	27	....	....	....
9	35	....	28	7	....	7
13	34	3	28	3	....	3
17	29	....	23	6	....	6
21	22	2	16	4	....	4
25	1	....	1	....	....	....
29	9	1	2	6	....	6
Aug. 1	9	....	5	4	2	2
5	14	....	4	10	....	10
9	11	1	1	9	....	9
13	13	2	....	11	9	2
17	36	....	....	36	12	24
21	101	2	....	99	46	53
25	100	17	....	83	43	40
28	109	14	....	95	44	51
Sept. 1	120	23	....	97	34	63
5	127	15	....	112	39	73
9	86	6	....	80	28	52
13	88	2	....	86	37	49
17	61	2	....	59	32	27
21	37	....	....	37	11	26
25	19	....	....	19	....	19
28	16	....	....	16	3	13
Oct. 2	18	....	....	18	....	18
5	22	3	....	19	....	19
9	17	1	....	16	3	13
14	8	....	....	8	....	8
18	5	....	....	5	....	5
22	6	1	....	5	....	5
27	....	....	....	....	....	....
Nov. 1	2	....	....	2	....	2
Total	1,418	183	283	952	343	609
Per cent	100	12.90	19.96	67.14	24.19	42.95

SUMMARY FOR SEASON OF 1912.

Spring-brood moths began emerging in the laboratory May 18 and probably several days earlier in the field. Ten to 12 days later first-brood larvæ were probably beginning to enter fruit. First-brood larvæ began leaving the fruit June 11. First-brood moths emerged July 2 to August 21, and second-brood larvæ probably were entering fruit by July 12. Soon after August 5 to 9 the number of larvæ appearing under the bands increased, and most of the larvæ taken after this date may be considered to be of the second brood.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

Figure 18 represents the occurrence of 608 moths of the spring brood that appeared in the rearing cages at Fishersville in 1913. Moths emerged first on May 3, but maximum emergence was delayed until May 30, the emergence curve in figure 18 for Fishersville being very different in this respect from the spring-brood curve at Winchester, as it appears in figure 14. Adults continued to emerge until June 27. (See also Table XXIV.)

TABLE XXIV.—*Emergence of spring-brood moths of the codling moth at Fishersville, Va., in 1913.* (See fig. 18.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 3	6	June 5	44
6	1	8	10
9	3	11	9
12	9	14	22
15	11	17	10
18	53	20	7
21	28	24	3
24	94	27	2
27	91		
30	124	Total	608
June 2	81		

First-brood larvæ were probably entering the fruit in the field by May 10 to 13, from eggs laid by moths emerging May 1 to 3.

On account of the light crop of fruit in 1913 the records at Fishersville for the remainder of the season are of little value and are not included in this report

INVESTIGATIONS AT FRENCH CREEK, W. VA.

DESCRIPTION OF LOCALITY.

French Creek is located near the lower border of the Transition Life Zone in a hilly region not far from the center of West Virginia. Commercial apple growing is just beginning to attract attention, and several orchards of considerable size are being planted in that general locality. Bearing orchards of from 5 to 25 acres are not uncommon. The orchards from which banding records were obtained are located at an approximate elevation of 1,600 feet above the level of the sea.

INVESTIGATIONS IN 1911.

On June 19, 1911, 15 suitable apple trees in an orchard that had never been sprayed were banded, but it was found that the bands were placed too late in the season to obtain a complete record of the time of emergence from the fruit of the first-brood larvæ. The bands furnished a supply of wintering larvæ to be used for emergence records of the spring brood of moths in 1912.

Predaceous and parasitic enemies of the codling moth were possibly more abundant here than in any other orchard in which banding records were made during the investigation. The second-brood larvæ were very extensively parasitized by hairworms (*Mermis* sp.). Of the larvæ of this brood, 71 out of 159, or nearly 50 per cent, died from this cause.

The first-brood moths began to appear in the jars on July 5, when five were found. The maximum was reached on July 8, and from that time the numbers gradually diminished until September 13, when the last two of the season appeared.

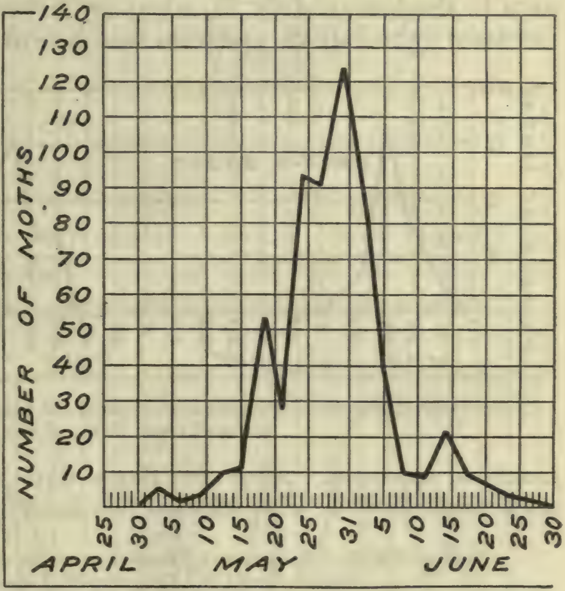

FIG. 18.—Diagram to illustrate emergence of spring-brood moths of the codling moth at Fishersville, Va., in 1913.

INVESTIGATIONS IN 1912.

SPRING-BROOD MOTHS.

On account of the high mortality, due to parasites and other causes, only about 50 wintering larvæ were alive to pupate in the spring. Pupation took place from April 22 to 28.

TABLE XXV.—*Emergence of spring-brood moths of the codling moth at French Creek, W. Va., in 1912.* (See fig. 19.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 13	1	May 25	16
14	2	29	4
16	3	June 1	2
21	8	Total	36

Table XXV shows that the first moths of this brood issued on May 13, the last on June 1, and the greatest number on May 25. The last petals were dropping from apple on May 10, so that the first moth appeared 3 days after the blossoms were off and the maximum moth emergence occurred from 10 to 12 days later.

FIRST-BROOD MOTHS.

As indicated in Table XXVI, first-brood moths made their appearance in the jars on July 20, when seven were found. The number increased up to July 28, and from that date until August 17 maximum numbers appeared. After the latter date the numbers decreased until September 11, when the last one issued.

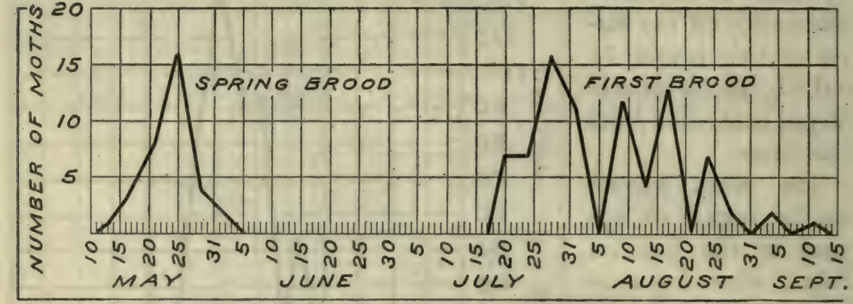

FIG. 19.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at French Creek, W. Va., in 1912.

TABLE XXVI.—*Emergence of first-brood moths of the codling moth at French Creek, W. Va., in 1912.* (See fig. 19.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 20	7	Aug. 24	7
24	7	28	2
28	16	31	
Aug. 1	11	Sept. 4	2
5		7	
9	12	11	1
13	4	Total	82
17	13		
21			

BAND COLLECTIONS.

About the middle of June, 12 apple trees were banded in an old orchard that had never been sprayed. The bands were examined twice each week. This year the larvæ were later by at least a week in beginning to leave the fruit than in 1911. The extent and dates of the collections are set forth in Table XXVII and figure 20.

TABLE XXVII.—*Record of codling-moth larvæ collected under bands at French Creek, W. Va., during the season of 1912.* (See fig. 20.)

Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.
June 24..	2	Aug. 5...	7	Sept. 18...	20
26..	0	9...	8	21...	22
29..	2	13...	10	25...	24
July 3...	5	17...	12	28...	13
6...	7	21...	12	Oct. 2....	8
10...	19	24...	6	5....	14
13...	12	28...	7	9....	8
17...	16	31...	5	12....	5
20...	10	Sept. 4....	17	16....	2
24...	16	7....	11		
28...	13	11...	10	Total .	339
July 31....	5	14...	11		

The first two larvæ were found on June 24. After June 26 the numbers increased with each collection until July 10. From that date until July 28 the size of the collections remained fairly constant. Collections were smaller from July 31 to August 13, after which time they increased until September 25, decreasing thereafter until October 16, when the last two were taken.

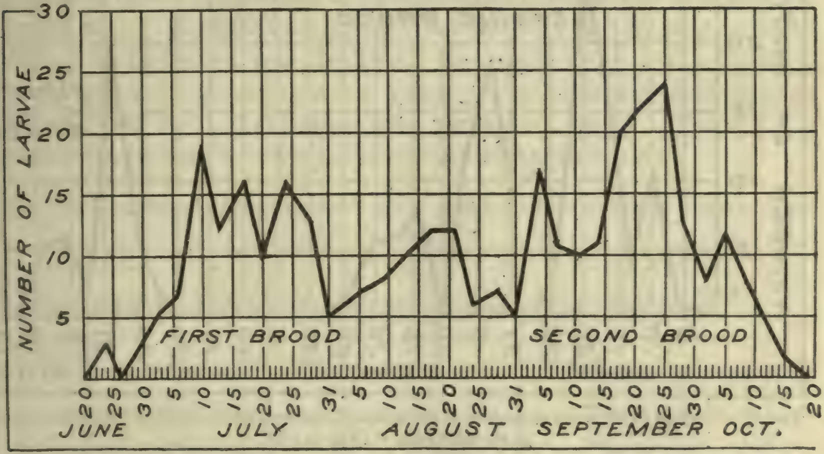

FIG. 20.—Diagram to illustrate band collections of codling moth larvæ at French Creek, W. Va., in 1912.

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

The details of the spring-brood moth emergence are set forth in Table XXVIII and are also shown graphically in figure 21.

TABLE XXVIII.—*Emergence of spring-brood moths of the codling moth at French Creek, W. Va., in 1913.* (See fig. 21.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
May 6	1	June 7	11
10	11	10	0
13	4	14	8
17	18	17	6
20	25	21	5
24	4	24	2
27	11		
31	9	Total	134
June 3	19		

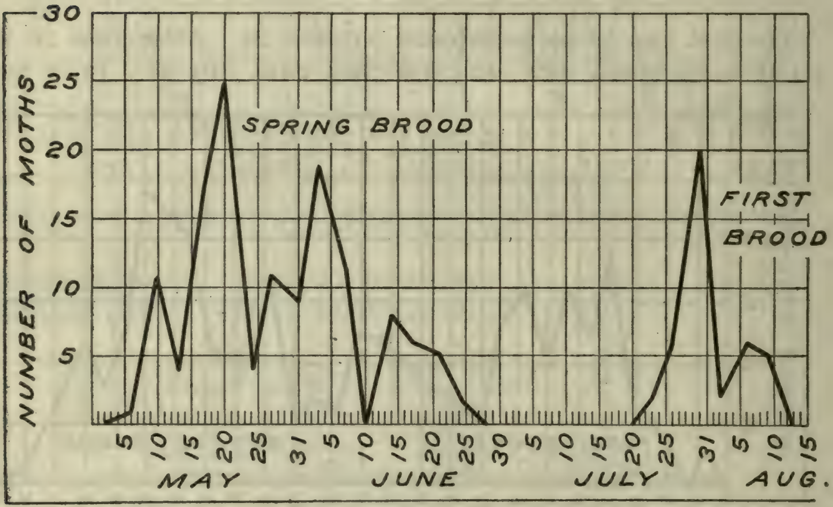

FIG. 21.—Diagram to illustrate emergence of spring-brood and first-brood moths of the codling moth at French Creek, W. Va., in 1913.

The first moth was found in the jars on May 6, the maximum numbers from May 17 to June 7, and the last on June 24. A freeze occurring on the night of April 20 caught the apple trees just coming into full bloom, practically destroying the entire crop of blossoms. The first moth appeared 16 days after the date of the freeze, and the maximum emergence was a little more than four weeks after the freeze.

FIRST-BROOD MOTHS.

Owing to the light crop of apples only a few larvæ were obtained, and the number of first-brood moths emerging was insignificant. Table XXIX shows the number that were obtained.

TABLE XXIX.—*Emergence of first-brood moths of the codling moth at French Creek, W. Va., in 1913.* (See fig. 21.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 23	2	Aug. 6	6
26	6	9	5
30	20	Total	41
Aug. 2	2		

It will be seen from this table that only 41 first-brood moths were obtained. Of these the first emerged on July 23, the maximum number on July 30, and the last on August 9.

BAND COLLECTIONS.

A period of cold, occurring April 20 and 21, when the temperature dropped to 20° F., followed by another drop to 25° F. on the night of May 10, destroyed practically all the apple crop in the locality. One old orchard containing a few bearing trees that were not sprayed was found and eight of the trees were banded on July 1. Table XXX shows the number of larvæ collected under these bands.

TABLE XXX.—*Record of codling-moth larvæ collected under bands at French Creek, W. Va., in 1913.*

Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.
July 5	6	Aug. 6	6	Sept. 6	4
9	17	9	4	10	1
12	19	13	7	13	2
16	18	15	6	17	2
19	5	20	7	20	0
23	8	23	6	24	1
26	10	27	4		
30	3	30	4	Total	143
Aug. 2	1	Sept. 3	2		

This table shows that the first larvæ were found under the bands on July 5, the greatest number, which was 19, on July 12, and the last on September 24. The second-brood larvæ were few in number, the collections being nearly uniform from August 6 to 23, after which time they decreased until the last was found.

INVESTIGATIONS AT PICKENS, W. VA.

DESCRIPTION OF LOCALITY.

The orchard at Pickens in which banding records were obtained in 1911 and 1912 is located in a mountainous region at an elevation of 3,500 feet above the level of the sea. The native flora and fauna of the immediate locality indicate the junction of the Transition and

Canadian Life Zones. Fruit growing is not extensively engaged in, although a considerable quantity of apples is produced and disposed of in lumber camps and other local markets.

The codling moth was less abundant here than in other localities where banding records were made. This was probably due to the higher elevation and the consequently shorter breeding season. Data were collected only in 1911 and 1912, the apple crop being an entire failure in 1913.

INVESTIGATIONS IN 1911.

On the 22d of June, 18 apple trees were banded in the orchard of Mr. Lewis Wunchner, 4 miles southeast of the village of Pickens. The orchard had never been sprayed and most of the trees banded were bearing heavy crops of fruit.

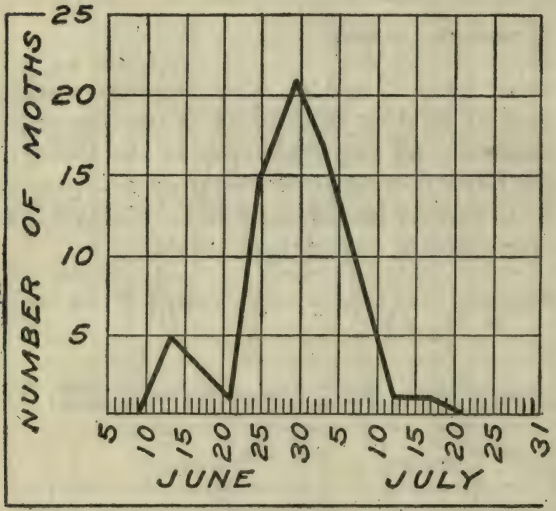

FIG. 22.—Diagram to illustrate emergence of spring-brood moths of the codling moth at Pickens, W. Va., in 1912.

BAND COLLECTIONS.

The first larvæ were found under the bands on July 7, on which date 27 were collected. The maximum number were found on July 19. The last were found on September 29, at which time the fruit was gathered from the trees by the owner of the orchard. The number of larvæ found had dropped from 75, on September 11, to 17 on September 29, and it is probable that only a few more individuals would have gone under the bands had the fruit remained on the trees longer. The details of the band collections are shown more fully in Table XXXI.

TABLE XXXI.—*Record of codling-moth larvæ and pupæ collected under bands at Pickens, W. Va., in 1911.*

Date of collection.	Number of larvæ.	Number of pupæ.	Total.	Number of larvæ wintering.	Per cent of larvæ wintering.
July 7	27		27		
19	82	36	118	4	3.5
29	36	7	43	6	13.9
Aug. 8	23	6	29	15	51.7
18	58	3	61	47	77
28	28	1	29	23	79.3
Sept. 11	75		75	75	100
29	17		17	17	100
Total number collected			399		

FIRST-BROOD MOTHS.

Table XXXII shows that of the 59 first-brood moths reared the first were found in the breeding jars on July 29, the maximum numbers from August 8 to 28, and the last on September 11.

TABLE XXXII.—*Emergence of first-brood moths of the codling moth at Pickens, W. Va., during the season of 1911.*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
July 29	14	Aug. 28	5
Aug. 8	20	Sept. 11	1
18	19	Total	59

INVESTIGATIONS IN 1912.

In 1912 the same orchard was used for the banding records as in 1911, although in most cases different trees were banded. Twelve trees were used.

SPRING-BROOD MOTHS.

Table XXXIII indicates the numbers and dates of emergence of this brood of moths at Pickens.

TABLE XXXIII.—*Emergence of spring-brood codling moths at Pickens, W. Va., during the season of 1912.* (See fig. 22.)

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 13	5	July 3	17
17	3	8	8
21	1	12	1
25	15	17	1
29	21	Total	72

Moths from the larvæ that had wintered in the rearing jars did not begin to emerge until nearly the middle of June, as is shown in the table. The first were found in the jars on June 13, the greatest numbers from June 25 to July 3, and the last on July 17.

BAND COLLECTIONS.

Larvæ were exceedingly scarce, as is shown in Table XXXIV, only 47 being taken under the bands during the entire season. The first was found on July 24 and the last on October 5. The numbers are so few that no distinct line can be drawn between the first and second broods.

TABLE XXXIV.—*Record of codling-moth larvæ collected under bands at Pickens, W. Va., during the season of 1912.*

Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.	Date of collection.	Number of larvæ.
July 24..	1	Aug. 24..	2	Sept. 18..	7
30..	2	28..	1	21..	1
Aug. 5..	....	31..	4	25..	5
10..	2	Sept. 4..	3	28..	5
14..	1	7	2	Oct. 5..	2
17..	1	11..	5		
21..	2	14..	1	Total..	47

INVESTIGATIONS IN 1913.

SPRING-BROOD MOTHS.

Of the 47 larvæ collected in 1912, 28 wintered and transformed to moths in 1913. Table XXXV shows the time of emergence.

TABLE XXXV.—*Emergence of spring-brood codling moths at Pickens, W. Va., during the season of 1913.*

Date of observation.	Number of moths emerging.	Date of observation.	Number of moths emerging.
June 21............	0	July 1............	8
24............	8	5............	4
28............	8	8............	0
		Total.......	28

The jars in which the larvæ had wintered were examined twice a week and on June 24 eight moths, which were the first of the season, were found. The same number were found on June 28, and also on July 1. The last were found on July 5.

RÉSUMÉ OF REARING EXPERIMENTS IN MARYLAND, VIRGINIA, AND WEST VIRGINIA.

Tables XXXVI and XXXVII summarize the rearing experiments of 1912 and 1913 in the different localities.

TABLE XXXVI.—*Résumé of rearing experiments on the codling moth at five points in Virginia, West Virginia, and Maryland in 1912.*

Observation.	Hagerstown, Md.		Winchester, Va.		Fishersville, Va.		Charlottesville, Va.		French Creek, W. Va.		Total.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Larvæ collected............	1,706	100.00	798	100.00	1,418	100.00	905	100.00	339	100.00	5,166	100.00
Larvæ dying from handling, cannibalism, etc....	448	26.26	217	27.19	183	12.90	164	18.12	80	23.60	1,092	21.12
Moths reared same season..	148	8.68	228	28.57	283	19.96	247	27.29	82	24.19	988	19.12
Moths reared following season................	404	23.68	219	27.44	609	42.95	355	39.23	134	39.53	1,721	33.31
Wintering larvæ............	1,110	65.06	342	42.86	952	67.14	494	54.59	172	50.74	3,070	59.42
Winter-killed larvæ........	706	41.38	120	15.04	343	24.19	139	15.36	38	11.21	1,346	26.06
Parasitized larvæ.........	......	......	14	1.76	......	......	......	......	5	1.47	19	.36

TABLE XXXVII.—*Résumé of rearing experiments on the codling moth at four points in Virginia, West Virginia, and Maryland in 1913.*

Observation.	Hagerstown, Md.		Winchester, Va.		Charlottesville, Va.		French Creek, W. Va.		Total.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Larvæ collected	2,756	100.00	971	100.00	542	100.00	143	100.00	4,412	100.00
Larvæ dying from handling, cannibalism, etc	883	32.04	234	24.10	223	41.14	48	33.58	1,388	31.46
Moths emerging same season	227	8.24	326	33.57	270	49.82	41	28.67	864	19.58
Wintering larvæ	1,646	59.72	346	35.63	49	9.04	51	35.66	2,092	47.38
Parasitized larvæ	......	......	65	6.70	......	......	3	2.09	68	1.55

It will be noted that the proportion of larvæ dying in the rearing cages, due to handling, cannibalism, disease, etc., varied from 12.90 per cent to 41.14 per cent. The latter figure, however, is unduly high, the average loss from this source being 21.12 per cent in 1912 and 31.46 per cent in 1913. The proportion of larvæ transforming the same season as that in which they were collected varied from 8.24 per cent at Hagerstown to 49.82 per cent at Charlottesville, with an average of 19.12 per cent in 1912 and 19.58 per cent in 1913. For 1912 from 42.86 per cent to 67.14 per cent of all larvæ collected spun up and wintered, the average for all points being 59.42 per cent. The proportion of wintering larvæ in 1913 was abnormally small on account of the light fruit crop of that year. Loss from winter killing amounted to from 11.21 per cent to 41.38 per cent, the average for all points being 26.06 per cent. Observations on parasitism were made only at Winchester and French Creek, the highest recorded being 6.70 per cent at Winchester in 1913. It must be remembered, however, that the foregoing facts are taken from observations of insects kept in confinement, and only in a limited way indicate what occurs under normal out-of-door conditions.

Table XXXVIII gives the numbers of codling-moth larvæ collected and reared in the course of the work in the different localities.

TABLE XXXVIII.—*Number of codling-moth larvæ collected and reared in the different localities in Virginia, Maryland, and West Virginia during 1911, 1912, and 1913.*

Locality.	Year.	Number of larvæ collected and reared.	Locality.	Year.	Number of larvæ collected and reared.
Charlottesville, Va	1911	1,218	Hagerstown, Md	1911	1.761
	1912	905		1912	1.706
	1913	542		1913	2,756
Greenwood, Va	1911	1.979	French Creek, W. Va	1911	633
	1912	1,862		1912	339
Fishersville, Va	1911	910		1913	143
	1912	1.418	Pickens, W. Va	1911	399
Winchester, Va	1911	2,079		1912	47
	1912	798			
	1913	971	Total	....	20,466

NUMBER OF FIRST-BROOD LARVÆ TRANSFORMING FIRST SEASON.

Table XXXIX shows the numbers of transforming and wintering band-collected larvæ of the first brood for several localities. These data are tabulated for their value in determining the relative size of the second brood of larvæ.

TABLE XXXIX.—*Number of first-brood larvæ of the codling moth transforming to moths the first season.*

Locality.	Year	Number of first-brood larvæ living to transform.	Number of first-brood larvæ transforming first season.	Per cent transforming first season.	Number of first-brood larvæ wintering.
Charlottesville, Va	1912	259	247	95.37	12
Do	1913	278	269	96.76	9
Hagerstown, Md	1912	1,122	147	13.19	974
Do	1913	1,356	227	16.74	1,129
Fishersville, Va	1912	308	278	90.26	30
Winchester, Va	1912	266	228	85.71	38
Do	1913	476	325	68.28	151
Keyser, W. Va	1911	226	221	97.78	5
French Creek, W. Va	1911	202	201	99.50	1
Do	1912	93	81	87.10	12
Pickens, W. Va	1911	154	59	38.31	95
Total		4,740	2,284	48.19	2,456

Since an indeterminate number of larvæ always die in the jars on account of artificial conditions, only those that lived to emerge as moths are considered in this table. It will be seen that there is a great variation in the percentage of the larvæ wintering in the different localities, and that in no case did all the first-brood larvæ transform to moths the first season. At Charlottesville, Fishersville, Keyser, and French Creek the proportion transforming the first season was so great as to insure nearly a full second brood of larvæ, while at Hagerstown and Pickens the large proportion wintering would indicate only a partial or scant second brood.

Where the banded orchards were bearing a full crop of fruit and other conditions were favorable for normal development of the larvæ, the relative sizes of the first-brood and second-brood band collections support the conclusions to be drawn from the data given in the table.

EFFECT OF DIFFERENCES IN ALTITUDE AND LATITUDE UPON THE DEVELOPMENT OF THE CODLING MOTH.

The stations at which the codling-moth rearing work reported in this paper was conducted comprise a range in altitude of 3,100 feet and in latitude of practically 1° 40′, or about 115 statute miles. In correlating the data from the various stations an effort has been made to determine whether or not definite differences in altitude and latitude have a corresponding and constant effect on the time of metamorphic changes in this species of insect. The results indicate that the codling moth in its development is so responsive to transient weather conditions and other local disturbing factors that the time of appearance of a certain brood in one locality can not be determined with certainty by any mathematical calculation based on the known time of appearance of the same brood in another locality of a known difference in altitude or latitude. It is probable that local differences in humidity, susceptibility to sudden changes in temperature as effected by topography, and, possibly, soil conditions, are more or less direct factors influencing the time of developmental changes in the insect.

In Table XL the results of these observations are given. In this table use is made of the law laid down some years ago by Dr. A. D. Hopkins that in phenological phenomena a fourth of a degree of latitude, or 100 feet in altitude, is equal to one day of time. The table shows that in this particular case the law does not apply. Charlottesville, being at the lowest altitude and the most southerly of the stations, is taken as a base and the other points considered in their relation thereto. In considering this table it should be borne in mind that data were collected but twice a week and that the dates given for the first appearance of the insect in its various stages may be from one to three days later than the actual occurrence. Differences in latitude that are equivalent to less than half a day are not considered; those equivalent to more than half a day are counted as full days.

TABLE XL.—*Effect of differences in altitude and latitude on the time of appearance of spring-brood and first-brood codling moths and first-brood larvæ.*

Locality.	Year.	Date of emergence of first spring-brood moths.	Date of first larvæ collected under bands.	Date of emergence of first-brood moths.	Elevation above sea level.	Elevation above Charlottesville.
					Feet.	*Feet.*
Charlottesville, Va.	1912	May 7	June 6	June 20	400	....
	1913	Apr. 18	June 5	June 14	400	....
Greenwood, Va.	1912	May 8	June 6	June 23	900	500
	1913	....	....	....	....	....
Hagerstown, Md.	1912	May 30	June 29	July 13	500	100
	1913	May 15	June 27	July 8	550	150
Winchester, Va.	1912	May 22	June 19	July 9	750	350
	1913	May 6	June 17	June 30	750	350
Fishersville, Va.	1912	May 18	June 11	July 2	1,500	1,100
	1913	May 3	June 14	....	1,500	1,100
French Creek, W. Va.	1912	May 13	June 24	July 20	1,600	1,200
	1913	May 6	July 5	July 23	1,600	1,200
Pickens, W. Va.	1912	June 13	July 31	Aug. 20	3,500	3,100
	1913	June 24	....	....	....	....

TABLE XL.—*Effect of differences in altitude and latitude on the time of appearance of spring-brood and first-brood codling moths and first-brood larvæ*—Continued.

Locality.	Year.	Distance north of Charlottesville. Degrees and minutes.	Distance north of Charlottesville. Miles.	Number of days later than Charlottesville according to law of latitude and altitude.	Actual number of days later than Charlottesville. First spring-brood moths.	Actual number of days later than Charlottesville. First larvæ under bands.	Actual number of days later than Charlottesville. First summer-brood moths.
		° ′					
Charlottesville, Va	1912						
	1913						
Greenwood, Va	1912	0 4	5	5	1	Same day	3
	1913						
Hagerstown, Md	1912	1 40	115	7	23	23	23
	1913			7	27	22	24
Winchester, Va	1912	1 10	80	8	15	13	19
	1913			8	18	12	16
Fishersville, Va	1912	0 4	5	11	11	5	12
	1913			11	15	9	
French Creek, W. Va	1912	0 50	60	15	6	18	30
	1913			15	18	30	39
Pickens, W. Va	1912	0 40	45	34	37	55	61
	1913			34	67		

RELATIVE NUMBERS OF LARVÆ ASCENDING AND DESCENDING THE TREES.

In 1911 several trees in a number of orchards were banded around the trunks and also around the bases of the larger branches. The lower bands were used to secure larvæ that had dropped with the infested fruit and ascended the trunk to spin up, and the upper bands were used for those that left the fruit before it dropped and descended toward the trunk for the same purpose. The following table shows the relative number of larvæ secured under the two sets of bands in the six orchards. In considering Table XLI due allowance should be made for an unknown number of larvæ that crawled across the bands or that spun up under the bark before reaching the bands.

TABLE XLI.—*Relative numbers of codling-moth larvæ collected from bands around the trunks and bases of branches, season of 1911.*

Locality.	Number of larvæ collected. On trunk.	Number of larvæ collected. On branches.	Number of larvæ collected. Total.	Per cent. On trunk.	Per cent. On branches.
Hagerstown, Md	543	602	1,145	47.42	52.58
Smithsburg, Md	179	619	798	22.44	77.56
Hancock, Md	75	91	166	45.18	54.82
Fishersville, Va	96	68	164	58.54	41.46
French Creek, W. Va	146	96	242	60.33	39.67
Pickens, W. Va	29	30	59	49.15	50.85
Total	1,068	1,506	2,574	41.49	58.51

SEASONAL EFFECT OF WEATHER CONDITIONS ON THE DIFFERENT STAGES OF THE CODLING MOTH.

The beginning of emergence of the spring-brood codling moths varies greatly from season to season, depending in any given year upon the temperature conditions that prevail during March, April, and May.

It will be noted, however, that in spite of the wide variation in the time of emergence of the spring-brood moths in 1912 and 1913 there was a tendency for the later stages of the insect to appear at more nearly the same periods both years. This is probably due to an equalization of midsummer weather conditions subjecting the later stages of the insect to the influences of a more constant seasonal temperature factor. At Winchester, where the codling moth was under closer observation than at other points, we find that while spring-brood moths emerged at least 10 days later in 1912 than in 1913, the second-brood larvæ began entering the fruit at practically the same time both years.

Hammar,[1] in his report on the codling moth in Pennsylvania, gives the following in his general summary:

> The time of the emergence of the spring brood of the moths is variable under different seasonal conditions and depends largely upon the relative lateness of the spring.
>
> The time of emergence of the summer brood, or first brood, of moths is fairly constant and generally commences about the 1st of August.

From the results of the band records and rearing work of 1912 and 1913 it would seem, therefore, that in all except very unusual seasons we may expect the feeding of second-brood larvæ to begin in the different sections about as follows: Charlottesville, Va., July 1; Fishersville, Va., July 10; Winchester, Va., July 15; Hagerstown, Md., July 25.

CANNIBALISM AMONG CODLING-MOTH LARVÆ.

During the progress of these studies it was noticed frequently that when a collection of codling-moth larvæ was confined in a rearing jar a considerable loss in their numbers from cannibalism was likely to occur. This habit, of the stronger larvæ devouring their weaker fellows, has been commented on by Hammar.[2] He states that cannibalism among the larvæ probably takes place also under normal conditions. In the jars the loss from this cause during the present investigations was frequently sufficient to amount to a considerable factor in influencing the number of moths to appear later.

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[1] Hammar, A. G. The codling moth in northwestern Pennsylvania. U. S. Dept. Agr., Bur. Ent., Bul. 80, Pt. VI, p. 111, 1910.

[2] Hammar, A. G. Life-history studies on the codling moth in Michigan. U. S. Dept. Agr., Bur. Ent., Bul. 115, Pt. I, p. 1-86, 1912. See p. 83.

NATURAL ENEMIES.

PREDACEOUS INSECTS.

It seems probable that many codling-moth larvæ, after leaving the fruit, are caught and destroyed by ants. A small red ant (*Solenopsis molesta* Say) was frequently met with on the bark of apple trees and under the bands engaged in killing and devouring the larvæ. Colonies of these ants that had their homes in the vicinity of banded trees seemed to form a habit of visiting the bands to obtain food. The collections of larvæ from trees in several localities were very considerably reduced in numbers from this cause. *Lasius niger* L. var. *americana* Emery, a species less abundant about the trees than the other, was also found killing the larvæ. These ants were determined by Prof. W. M. Wheeler.

Several species of beetles were found to be predatory on the larvæ and pupæ at the various stations. The most abundant of these was *Tenebroides corticalis* Melsh., both the larvæ and adults of which were frequently found under the bands devouring the larvæ and pupæ. Another beetle, *Hololepta lucida* Lec. (Pl. I, fig. 2), was found at Winchester with a codling-moth larva in its jaws. Two species of carabid beetles (*Calanthus opaculus* Lec. and *Platynus angustatus* Dej.) were common under the bands but were not observed to be feeding on the codling-moth larvæ. These beetles were determined by Mr. E. A. Schwarz, of the Bureau of Entomology. A coleopterous larva, which was determined as a species of Telephorus by Mr. H. S. Barber, was observed in the act of eating a codling-moth larva at Hancock in 1911.

HYMENOPTEROUS AND DIPTEROUS PARASITES.

Six species of hymenopterous parasites were reared from the codling-moth larvæ in the jars. Of these, *Ascogaster carpocapsæ* Vier. (Pl. I, fig. 1) was found at Winchester, Hagerstown, Smithsburg, Keyser, and French Creek, and outnumbered all others. An undetermined secondary parasite was found to be destroying this species in considerable numbers at Keyser in 1911. *Itoplectis marginatus* (Prov.) (fig. 23) occurred at Greenwood, Hagerstown, Winchester, and French Creek. A female of this species was observed on the trunk of an apple tree at French Creek ovipositing in a larva that had spun up under a scale of bark. *Macrocentrus* sp.[1] was reared at Greenwood in July, 1911; *Meteorus* sp.,[2] at French Creek in July, 1913; (*Microdus*) *Bassus*, n. sp. (Pl. I, fig. 4), at Smithsburg in July, 1911; and *Phanerotoma tibialis* Hald. at Charlottesville in 1911. The last species was determined by Mr. H. L. Viereck and the others by Mr. R. A. Cushman, of the Bureau of Entomology.

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[1] Quaintance No. 7457.

[2] Quaintance No. 7569.

A dipterous parasite, reared from codling-moth larvæ at Keyser in 1911, was determined by Mr. W. R. Walton, of the Bureau of Entomology, as (*Hypostena*) *Tachinophyto variabilis* Coq. (Pl. I, fig. 3). Only a few specimens of this species were obtained.

HAIRWORM PARASITES.[3]

Hairworm parasites of the codling moth (Pl. I, figs. 5, 6) were found at Greenwood, Keyser, and French Creek, being abundant in the second-brood larvæ at the latter place in 1911. These parasites were within the bodies of the codling-moth larvæ at the time collections were made from the bands and usually issued from their hosts 10 days or 2 weeks after the larvæ were placed in the rearing jars. Occasionally dead larvæ, surrounded by a mass of dead hairworms, were found under the bands, and in a few cases the hairworms were found within apples borne by the banded trees. It was evident that infestation occurred at an early stage in the larval development and that all infested individuals died as full-grown larvæ. Most of the parasitized larvæ died within 10 days after being placed in the rearing jars.

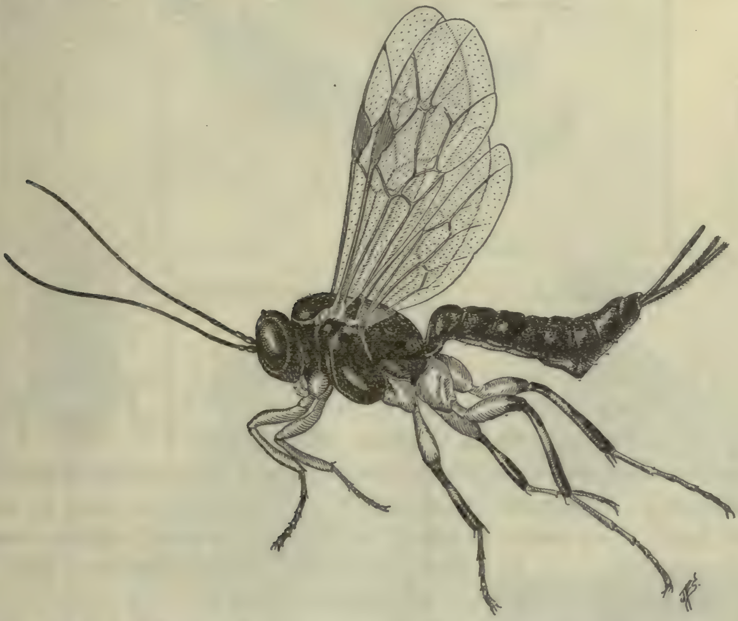

FIG. 23.—*Itoplectis marginatus*, a parasite of the codling moth. Enlarged. (Original.)

The hairworms were from 2½ to 5 inches in length, and three or four were frequently observed to inhabit one larva. In leaving the host they passed through the anal opening or broke through the skin at some other point. After freeing themselves from the host, all that were observed writhed about actively for a few minutes and then died. Many of the hairworms did not escape from the codling-moth cocoons, but were found, at the time of the regular examinations of the jars, knotted together and dead, beside the flattened and shriveled larval remains. Table XLII shows the extent of parasitization at French Creek in 1911.

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[3] *Mermis* sp. Material was referred to Dr. B. H. Ransom, of the Bureau of Animal Industry, but as the specimens were all immature, they could not be determined specifically.

TABLE XLII.—*Extent of parasitization of codling-moth larvæ by hairworms at French Creek, W. Va., in 1911.*

Date larvæ were collected.	Number of larvæ collected.	Number of larvæ parasitized.	Per cent parasitized.
June 26	139	0	....
July 3	68	0	....
July 14	48	6	12.50
July 24	24	1	4.17
Aug. 4	14	3	21.43
Aug. 15	51	7	13.72
Aug. 23	34	11	32.35
Sept. 2	36	23	63.90
Sept. 13	43	21	48.84
Sept. 19	23	10	43.48
Oct. 3	22	6	27.27
Total	502	88	17.53

SUMMARY.

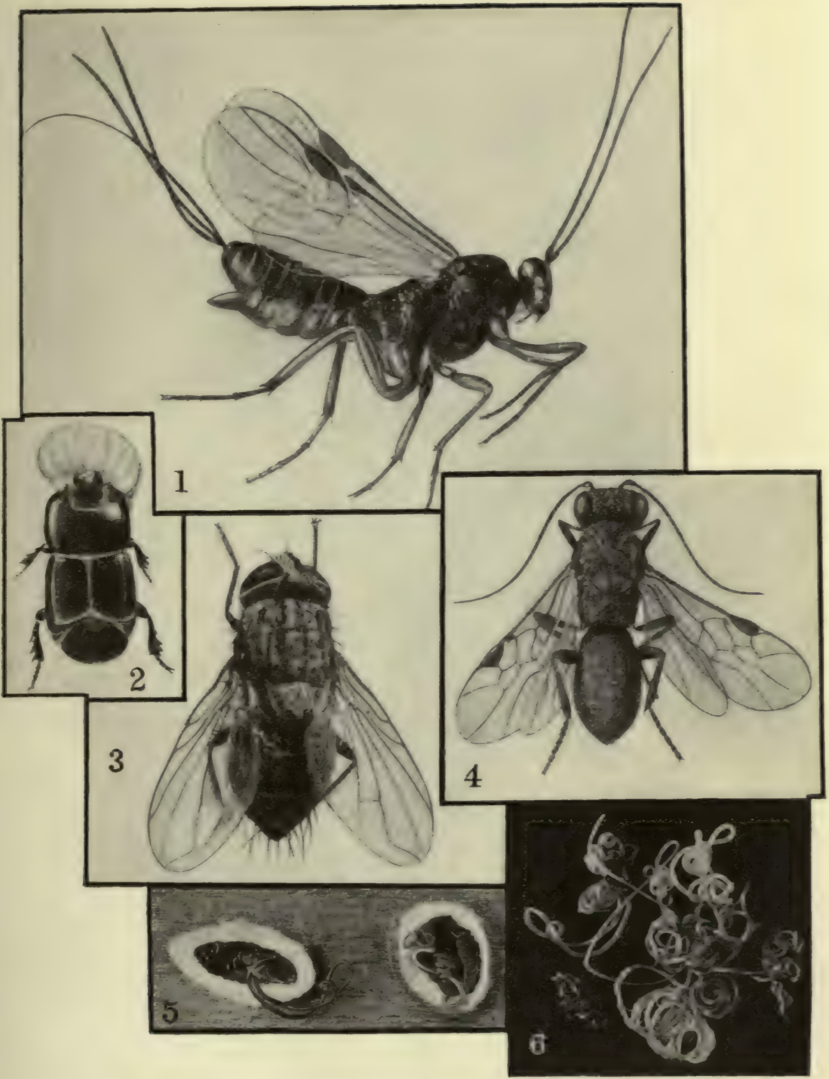
The foregoing account of the codling moth is based upon band-record studies conducted in 1911, 1912, and 1913 in several different localities of Virginia, West Virginia, and Maryland.

The stations at which the investigations were conducted comprise a difference in latitude of about 1° 40′ and in altitude of about 3,100 feet. The most southerly and least elevated station was at Charlottesville, Va., the most northerly at Hagerstown, Md., and the one at highest elevation at Pickens, W. Va.

The chief features of the investigations consisted of banding suitable apple trees with strips of burlap, collecting at regular periods the larvæ that went beneath the bands to spin up, and rearing these larvæ in jars kept in the localities where the larvæ were collected. Examinations of the bands and rearing jars were made every week or ten days in 1911 and twice a week in 1912 and 1913. No detailed life-history studies were attempted.

During a single year the codling moth, in the region covered by the present studies, produces one full brood of larvæ and a partial second brood, the size of the second brood depending more or less on the latitude and altitude of the locality.

The studies show a marked difference in the time of appearance of the different broods in different localities. Charlottesville gave the earliest records for practically all broods and Pickens the latest.



NATURAL ENEMIES OF THE CODLING MOTH (CARPOCAPSA POMONELLA).

Fig. 1.—*Ascogaster carpocapsae.* Fig. 2.—*Hololepta lucida* devouring codling-moth larva. Fig. 3.—(*Hypostena*) *Tachinophyto variabilis.* Fig. 4.—(*Microdus*) *Bassus* n. sp. Fig. 5.—Codling-moth larvæ killed in cocoons by hairworms (*Mermis* sp.). Fig. 6.—Mass of hairworms (*Mermis* sp.) taken from rearing jar, French Creek, W. Va. (Original.)

There seems, however, to be no constant rate of difference between the earlier and later localities. This seems to be largely due to the responsiveness of the species during its metamorphic changes to local and transient weather conditions.

During the time of the investigation the first-brood larvæ began entering the fruit at Charlottesville from April 28 to May 15, and second-brood larvæ from June 25 to July 1. At Pickens first-brood larvæ began entering the fruit from June 20 to July 1, and second-brood larvæ about August 10. Between these two localities there is a greater difference in the time of the regular periodical changes of the insect that occur late in the season than of those that occur early in the season. This is probably due to the cumulative retarding effect of the more frequent unfavorable weather conditions at the higher point.

For any given locality the variation in the time of appearance of spring broods in different years is greater than that of corresponding summer and fall broods of the same years.

Records of the numbers of larvæ collected from trees on which bands were placed around the trunks and also around the bases of the larger branches indicate that 41.49 per cent drop to the ground and then ascend the trunk to pupate and 58.51 per cent crawl down the branches from the infested fruit to pupate.

Where a collection of larvæ is confined in one jar there is apt to be a considerable loss due to cannibalism. It is probable that the weaker larvæ are sometimes devoured by their fellows under normal conditions.

Two specimens of ants (*Solenopsis molesta* Say and *Lasius niger* L. var. *americana* Emery) were found in several localities devouring codling-moth larvæ. Larvæ and adults of the beetle *Tenebroides corticalis* Melsh. were found frequently feeding on codling-moth larvæ and pupæ. Six species of hymenopterous and one of dipterous parasites were reared in the jars. Of these the most destructive to the codling moth were *Ascogaster carpocapsæ* Vier. and *Itoplectis marginatus* Prov. Hairworm parasites (*Mermis* sp.) were abundant in one locality and very materially reduced the number of wintering larvæ in the year 1911.

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2

HOW TO DETECT OUTBREAKS OF INSECTS AND SAVE THE GRAIN CROPS

W. R. WALTON

Entomologist in Charge of Cereal and Forage Insect Investigations

A billbug, much enlarged

FARMERS' BULLETIN 835

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. June, 1917

Additional copies of this bulletin may be obtained free from the
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MAXIMUM YIELDS of grain must be produced not only during the present year but for several years to come. The present international situation renders this imperative. Insects are responsible for great reductions in grain crops annually, but such losses are largely preventable. The injuries caused by insects often remain unnoticed except where their work is very conspicuous.

Therefore, WATCH THE CROPS CAREFULLY FOR EVIDENCES OF INSECT INJURY AND APPLY REMEDIES PROMPTLY. This bulletin will tell you how to fight the Hessian fly, chinch bug, army worm, cutworms, grasshoppers, white grubs, billbugs, corn root-aphis, and wireworms.

Keep in close touch with your county agricultural agent, State experiment station, or Federal entomological station. Report all serious insect outbreaks to these officials and seek their expert advice in all cases of doubt regarding treatment for, or identity of, insect pests. Have a supply of insecticides and a practical spraying outfit on hand at all times. WATCH YOUR CROPS.

HOW TO DETECT OUTBREAKS OF INSECTS AND SAVE THE GRAIN CROPS.

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A GREAT portion of the annual loss to the grain crop due to insect injuries can be avoided by vigilance and vigorous action on the part of the grain growers. Insect outbreaks frequently originate within limited areas, and when this is the case it often is possible to stamp them out before any great damage has occurred. In other instances the outbreaks are of general origin, and then community action is essential in order that the inroads of the pest may be overcome. The most serious insect enemies of cereal crops, such as the Hessian fly, the chinch bug, and white grubs, belong to the latter class. In the case of these and other widely distributed foes of the grains no means of stopping their ravages will be fully successful until community action can be secured in adopting the methods of combat at present advocated by entomologists.

Fall plowing, doubtless, is the most universally beneficial practice for the control of the insect pests of cereal crops, and this measure should be adopted except where it is rendered impossible by local agricultural conditions. Corn never should be planted on freshly broken sod land, because this practice is almost certain to expose the crop to the ravages of cutworms, wireworms, and white grubs. Crops belonging to the bean family, such as cowpeas, soy beans, clover, alfalfa, etc., may be interposed safely between sod and grain and especially between sod and corn, in order that injury to the grain crops by these pests may be avoided.

HESSIAN FLY.[1]

The Hessian fly, found throughout almost the entire winter-wheat region (fig. 1), is a minute, mosquitolike fly which lays its eggs upon

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[1] *Phytophaga destructor* Say.

MAXIMUM YIELDS of grain must be produced not only during the present year but for several years to come. The present international situation renders this imperative. Insects are responsible for great reductions in grain crops annually, but such losses are largely preventable. The injuries caused by insects often remain unnoticed except where their work is very conspicuous.

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A GREAT portion of the annual loss to the grain crop due to insect injuries can be avoided by vigilance and vigorous action on the part of the grain growers. Insect outbreaks frequently originate within limited areas, and when this is the case it often is possible to stamp them out before any great damage has occurred. In other instances the outbreaks are of general origin, and then community action is essential in order that the inroads of the pest may be overcome. The most serious insect enemies of cereal crops, such as the Hessian fly, the chinch bug, and white grubs, belong to the latter class. In the case of these and other widely distributed foes of the grains no means of stopping their ravages will be fully successful until community action can be secured in adopting the methods of combat at present advocated by entomologists.

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HESSIAN FLY.[1]

The Hessian fly, found throughout almost the entire winter-wheat region (fig. 1), is a minute, mosquitolike fly which lays its eggs upon the leaves of wheat. These eggs hatch into little maggots which crawl down into the leaf sheaths. There they live upon the plant's sap, which they obtain by gnawing into the soft portions of the stem. Usually two, but sometimes three or more, generations of the insect occur during a year.

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[1] *Phytophaga destructor* Say.

One main generation of flies (see fig. 2) appears in the fall, the large proportion of the maggots becoming full-grown before the severe weather of winter arrives, when they change into brown seedlike forms known as "flaxseeds." These may be found within the leaf sheaths in young wheat plants, usually at or beneath the surface of the soil. These overwintering "flaxseeds" produce the spring generation of flies. These, in turn, lay eggs from which hatch maggots that cause great injury to wheat, noticed about harvest time, when the straws break off and the crop is said to be "straw fallen."

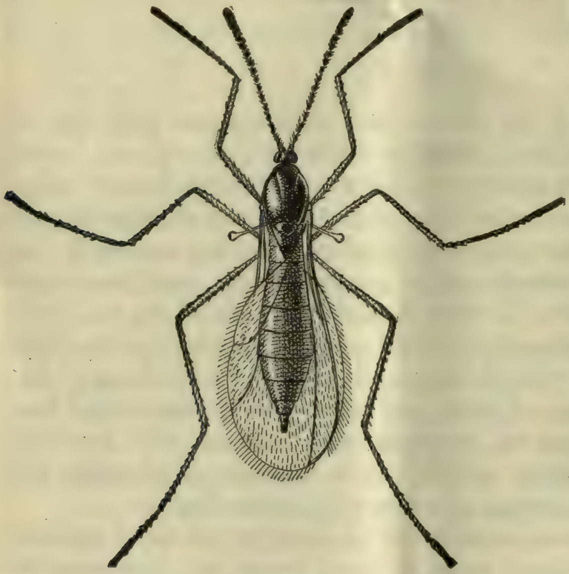

FIG. 1.—The Hessian fly (*Phytophaga destructor*): Adult female. Much enlarged.

After the Hessian fly has once thoroughly infested the crop of wheat there is no known means of saving it, and the only known means of preventing damage from the fly is to keep it out of the wheat.

For this reason the young wheat should be examined thoroughly in order that the presence of the brown "flaxseeds" may be detected late in winter or very early in the spring, and if these are found to be present in large numbers it will pay to plow down the wheat at once and prepare to plant corn, oats, or some other crop in its place. In this way the fertilizing value of the green crop will be retained in the soil and it will still be possible to secure a crop of grain or vegetables from the field during the current year.

The remedies for the Hessian fly are entirely preventive and are as follows:

(1) Immediately after harvest, or as soon thereafter as practicable, plow the wheat stubble down deeply, at least 5 inches deep if possible, in order to destroy the maggots and "flaxseeds" which may remain in it. This is for the protection of future crops.

(2) Pay great attention to the preparation of the seed bed for the wheat by plowing early and working and packing the soil thoroughly in order to eliminate lumps and clods, thus producing a finely pulverized, compact, and moisture-conserving bed for the seed.

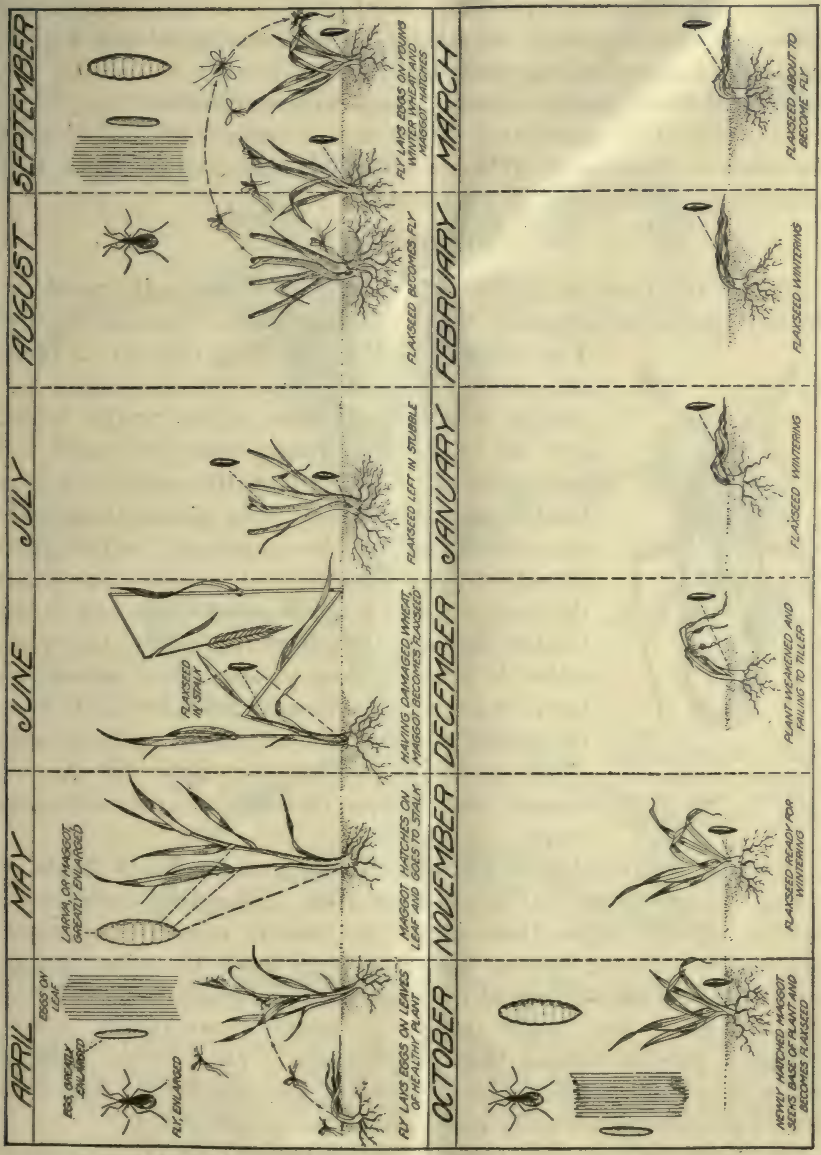
APRIL
EGGS ON LEAF
EGGS, GREATLY ENLARGED
FLY, ENLARGED
FLY LAYS EGGS ON LEAVES OF HEALTHY PLANT
MAY
LARVA, OR MAGGOT, GREATLY ENLARGED
MAGGOT HATCHES ON LEAF AND GOES TO STALK
JUNE
FLAXSEED IN STALK
HAVING DAMAGED WHEAT, MAGGOT BECOMES "FLAXSEED"
JULY
FLAXSEED LEFT IN STUBBLE
AUGUST
FLAXSEED BECOMES FLY
SEPTEMBER
FLY LAYS EGGS ON YOUNG WINTER WHEAT AND MAGGOT HATCHES
OCTOBER
NEWLY HATCHED MAGGOT SEEKS BASE OF PLANT AND BECOMES FLAXSEED
NOVEMBER
FLAXSEED READY FOR WINTERING
DECEMBER
PLANT WEAKENED AND FAILING TO TILLER
JANUARY
FLAXSEED WINTERING
FEBRUARY
FLAXSEED WINTERING
MARCH
FLAXSEED ABOUT TO BECOME FLY

FIG. 2.—Diagram showing seasonal development of the Hessian fly.

(3) *Destroy all volunteer wheat* by plowing or disking, as such wheat serves to carry the flies over from fall to spring, even though most of the fields of wheat have been treated properly and contain no flies. *One field in which volunteer wheat is allowed to remain may*

breed enough Hessian flies to infest a whole neighborhood where the grain is otherwise free from the fly.

(4) Take care that the sowing of wheat in the fall is delayed until the fly-free date. Information regarding this date can be obtained by applying to your county agricultural agent, your State experiment station, or to the nearest entomological field station of the United States Department of Agriculture.

(5) Practice a good rotation of crops wherever possible.

(6) Secure the cooperation of the entire community in following the methods mentioned. This is absolutely essential in order that satisfactory results may be obtained.[1]

CHINCH BUG.[2]

Next to the Hessian fly the chinch bug doubtless is the most destructive pest affecting cereal crops. It does greatest damage to corn. The adult or full-grown bug (fig. 3) is black and about one-eighth of an inch in length, and usually bears conspicuous white wings folded over its back. The young ones are bright red and wingless. The old bugs live over the winter hidden among clumps of wild grasses, especially those known as the "broom sedges," which grow abundantly in uncultivated places throughout the greater portion of the main wheat belt of the United States. *It is most important, therefore, either to prevent these grasses from accumulating in waste or uncultivated fields or else to burn them over while dry during the late fall or early in the spring, before the bugs have left the dry grasses and become distributed over cultivated crops.*

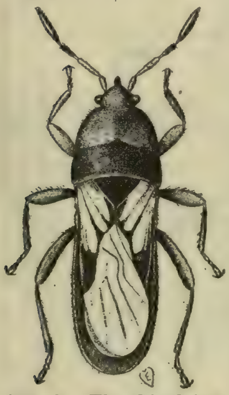
FIG. 3.—The chinch bug (*Blissus leucopterus*): Adult, long-winged form. Much enlarged.

It is the usual habit of the chinch bug first to attack fields of wheat, rye, or barley, and its presence often is unnoticed because the injuries inflicted upon these crops are obscure or of no apparent importance. About harvest time the bugs leave the small grains and crawl over the surface of the ground to the nearest fields of corn (fig. 4), where they begin at once to wreak severe injury. *It is, therefore, very important that the presence of the bugs be detected before they have reached the corn and if possible before they have started to migrate from the small grains to the cornfields.*

Cornfields may be protected and the migrating bugs trapped about the time of wheat harvest, as follows: Plow a deep furrow along the edge of the field, running the land side of the plow toward the field to be protected. In dry weather the sides of the furrow can be made so smooth and the sides so steep that the bugs will find it easier to crawl along the bottom than to climb up the sides. Circular holes from 30 to 40 feet apart, made with a post-hole digger, then may be dug in the bottom of the trench. Into these holes the bugs will fall in large numbers, and here they may be killed easily by sprinkling kerosene oil over them. A log dragged back and forth along the furrow is useful in keeping the bottom and sides in good condition during dry weather. In wet weather a line of liquid tar or crude petroleum, which the bugs will not cross, may be maintained in the furrow bottom.

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[1] Further information regarding this pest is contained in Farmers' Bulletin 640, which may be secured free of charge upon application to the Secretary of Agriculture, Washington, D. C.

[2] *Blissus leucopterus* Say.

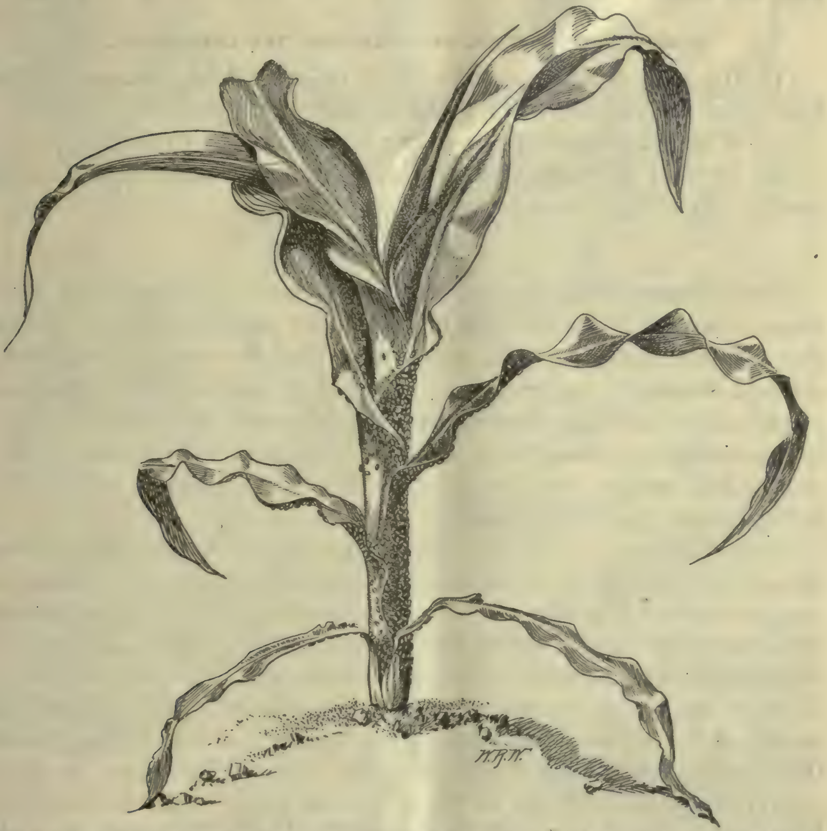

FIG. 4.—Corn plant infested with chinch bugs. When the bugs are as numerous as this on the corn it can not be saved. *Do not let them reach the corn.*

Spraying for chinch bugs has not proved successful except on a small scale and when conducted by an expert, the difficulty being that the substances which kill the bug are almost sure to kill the corn also. *The thing to do is to discover the bugs before they reach the corn and keep them out of it by the methods described above.*

In case the bugs have reached only the first few rows of corn, however, they may be killed by spraying with a solution of one of the commonly used commercial washing powders prepared as follows: Dissolve 1 pound of washing powder in 2 gallons of boiling water. This is to be used as a stock solution; when ready to spray, dilute by adding 2 gallons of cold water to 1 of the stock solution, and apply to the infested rows with an ordinary force pump and sprayer. In order to be effective the soap-powder solution must come into contact with the bugs.

SUMMARY OF CONTROL MEASURES FOR THE CHINCH BUG.

(1) Burn the dried grasses in which the chinch bug winters, either late in the fall or very early in the spring.

(2) Watch for the bugs in young wheat, rye, or barley.

(3) Prevent the bugs from traveling from the small grains to the corn by ditching, as described.[1]

ARMY WORM.[2]

Watchfulness is the key to success in cases of invasion by army worms (see fig. 5), which are the young of certain moths or millers that fly only at night. The eggs from which the army worms hatch are laid commonly on grasses or grasslike grains and the tiny caterpillars, upon hatching, feed for several days near the ground, hidden by overhanging grasses or grains and thus may escape notice until nearly full grown, by which time they have become widely distributed over the infested fields.

Upon the discovery of the pest in its younger stages depends very largely the possibility of stamping out infestations before serious injury to crops has occurred. Meadows therefore should be examined frequently during the spring and early summer months, particularly those planted to timothy, bluegrass, wheat, and especially millet, to discover the young worms. One should not be satisfied with looking merely at the surface of the stand; the thicker and longer the growth, the greater the danger from the army worm. The grass or grain should be parted with the hands in various parts of the field and the lower portions of the growth examined closely, in order that the presence of the small, greenish caterpillars may be discovered, and if these be found in any number the area covered by the infestation should be determined and vigorous action taken at once to destroy the worms before they become large enough to begin their journey to other parts of the farm. If the infested spot be small, the grass or grain can be mowed off and straw scattered over the spot and burned, thus destroying the worms. If the caterpillars have become dis-

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[1] Additional information regarding the chinch bug is contained in Farmers' Bulletin 657, which may be secured free of charge by application to the Secretary of Agriculture, Washington, D. C.

[2] *Cirphia unipuncta* Haw.

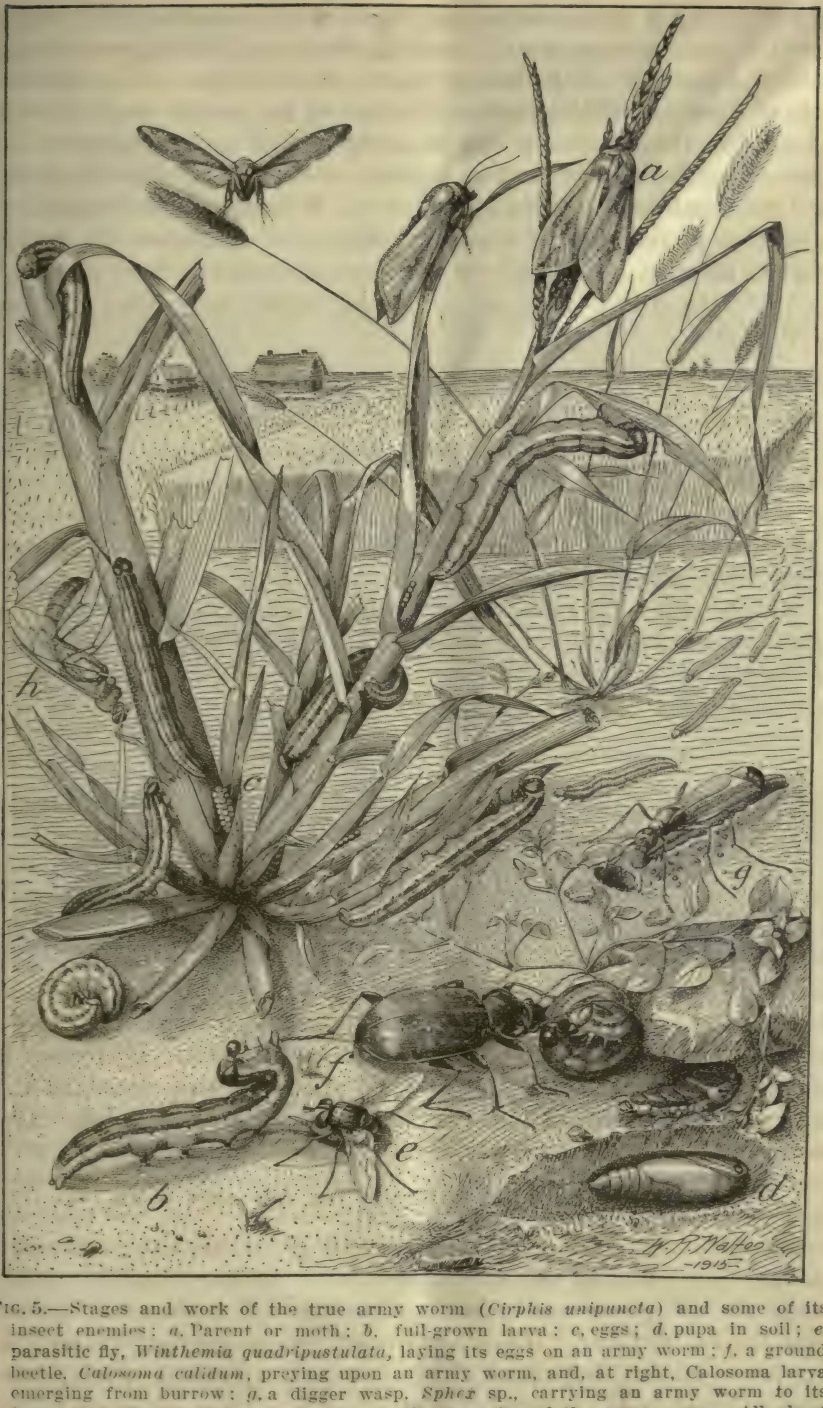

FIG. 5.—Stages and work of the true army worm (*Cirphis unipuncta*) and some of its insect enemies: *a*, Parent or moth; *b*, full-grown larva; *c*, eggs; *d*, pupa in soil; *e*, parasitic fly, *Winthemia quadripustulata*, laying its eggs on an army worm; *f*, a ground beetle, *Calosoma calidum*, preying upon an army worm, and, at right, Calosoma larva emerging from burrow; *g*, a digger wasp, *Sphex* sp., carrying an army worm to its burrow; *h*, *Enicospilus purgatus*, a wasplike parasite of the army worm. All about natural size.

tributed over a considerable area, this can be marked off by stakes and the crop sprayed heavily with a solution of Paris green at the rate of 1 pound to 50 gallons of water, or of arsenate of lead at the rate of 2 pounds of the paste or 1 pound of the powder to 50 gallons of water. In case this poison is used, care should be exercised in preventing stock from gaining access to the poisoned grass or grain and being injured or killed by eating it. It is best by far to sacrifice a portion of the crop, if the destruction of the pest can be accomplished thereby, because if the army worms are not destroyed they will take the crop in any case and probably devastate other portions of the farm.

POISONED BAITS FOR THE ARMY WORM.

Poisoned baits have long been used as a means of destroying the numerous species of cutworms and also the army worm. An efficient bait of this kind may be prepared and used as follows: To 50 pounds of wheat bran and 1 pound of Paris green or 2 pounds of powdered arsenate of lead add the juice of one-half dozen oranges or lemons. Then bring the mass to a stiff dough by adding low-grade molasses or sirup, preferably molasses, and scatter the mixture broadcast in small pieces throughout the infested field. This poisoned bait may be used safely in alfalfa and cornfields where it is desired, if possible, to save the crop for forage.

MECHANICAL MEASURES AGAINST THE ARMY WORM.

In case the worms are not discovered until they have begun to travel in a mass, usually they can be destroyed by furrowing or ditching completely around the infested area (see fig. 6). The worms will fall into the ditches and can be killed easily by crushing them with a log dragged back and forth through the ditch or furrow. If shallow postholes are sunk in the bottom of the ditch at intervals of about 20 feet, the worms will crawl along the ditch bottoms and fall into the holes, where they may be destroyed by crushing or other means. If the subsoil be of such a nature that water penetrates it but slowly, the postholes may be filled partially with water, on the top of which a layer of coal oil or petroleum may be poured. The worms die almost immediately upon falling into such holes.

SUMMARY OF CONTROL MEASURES FOR THE ARMY WORM.

(1) Watch fields of growing grass and grain carefully, especially the meadows, during the spring and early summer months, to discover the army worms before they become full grown and spread over the entire farm. *When the worms are discovered at work, do not lose a minute, but attack them vigorously by means of the measures outlined in the foregoing pages.*

(2) Poison them by spraying crops not intended for forage with 1 pound of Paris green to 50 gallons of water, or with 2 pounds of powdered arsenate of lead to 50 gallons of water. In case the Paris green is used on tender plants, like corn, add 2 pounds of freshly slaked lime to 50 gallons of the mixture. This is to prevent burning the tender plants. Where spraying is not practicable, the use of the poisoned-bran bait already mentioned is strongly recommended.[1]

(3) In case the worms are crawling in a body, surround them with a furrow or ditch and crush them with a log drag as they fall into it.

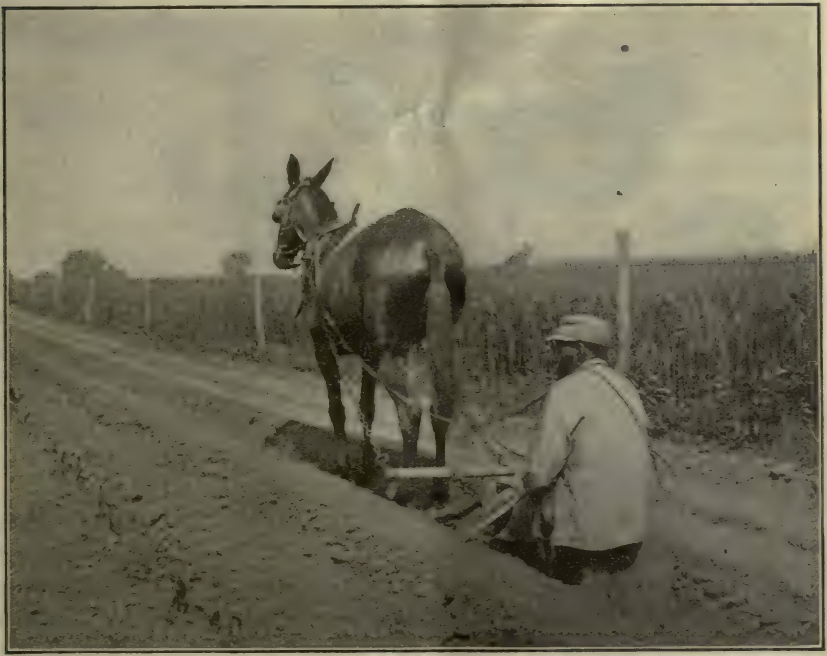

FIG. 6.—Ditch prepared to entrap marching army worms. A log, dragged back and forth through the ditch, crushes the worms that have fallen into it.

CUTWORMS.

Numerous complaints of the ravages of cutworms (see fig. 7), especially in corn, are received by the department each season. Prompt action is necessary for controlling cutworms after their presence becomes noticeable in the spring, which usually is about the time the corn begins to sprout. *Since the crop may be destroyed by cutworms between the time an inquiry is sent to the department upon the appearance of the worms and the time a reply can be received, the importance of recognizing these insects and knowing how to control them is evident.*

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[1] Further information regarding this pest is contained in Farmers' Bulletin 731, which may be secured free of charge upon application to the Secretary of Agriculture, Washington, D. C.

Cutworm injury, which usually consists in the cutting off of the plants at or a little below the surface of the ground, almost invariably occurs in the spring, beginning as soon as the first plants sprout and continuing until late June or early July, by which time the worms are full grown. The worms feed at night and rest during the day beneath débris or in the soil from one-half to 1 inch below the surface, and since in most cases they resemble the soil closely in color the cause of the injury often is not apparent. However, if the soil surrounding the cut-off plant be examined carefully, the culprit probably will be found curled up beneath the surface as shown at *c* in figure 7.

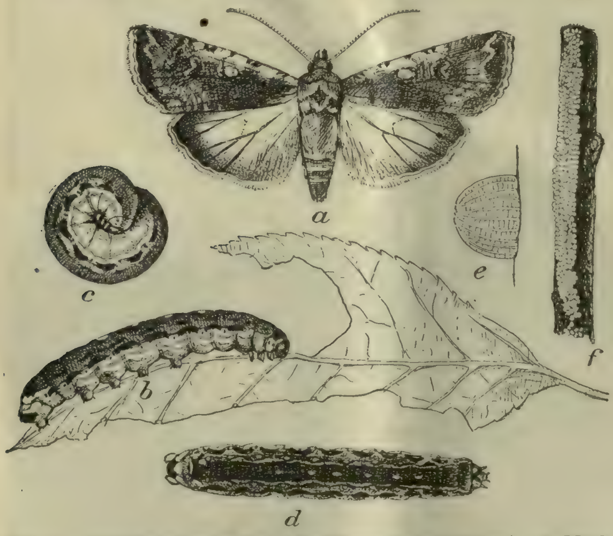

Fig. 7.—Variegated cutworm (*Peridroma margaritosa*) : *a*, Moth ; *b*, normal form of caterpillar, side view ; *c*, same in curved position ; *d*, dark form, view of back ; *e*, greatly enlarged egg, seen from side ; *f*, egg mass on twig.

SEASONAL HISTORY OF CUTWORMS.

The various species of cutworms are known under a number of names, such as glassy cutworm, greasy cutworm, variegated cutworm, clay-backed cutworm, etc., but the injuries caused by them are very similar and their habits in general are also much the same. The parents of cutworms are grayish or brownish moths, or "millers," which commonly occur at lights during summer evenings. Each moth may lay from 200 to 500 eggs (see fig. 7, *e*, *f*), either in masses or singly, in fields covered with dense vegetation, and hence the eggs are to be found more often than elsewhere in cultivated fields which have been in grass or weeds the preceding fall. The eggs hatch in the fall, a few weeks after they are laid, usually during September, and the young cutworms, after feeding on grass and other vegetation until cold weather, pass the winter as partly grown caterpillars. If an infested field is left to grass, no noticeable injury is likely to occur; but when it is broken up and planted to corn or other wide-row crops, the worms, suddenly being placed on "short rations," play havoc with the newly planted crops, the nearly full-grown worms feeding greedily and consuming an enormous amount of food. In northern latitudes they attain full growth and stop feeding in late

June or early July, and then change to the pupal or resting stage. The injury often ceases so suddenly that farmers are at a loss to account for the fact.

CONTROL OF CUTWORMS.

If land that has been in grass for a considerable time and is likely to contain cutworms is to be planted to corn the following spring, it should be plowed in midsummer or early fall, about the time the eggs are laid or, better, before the eggs are laid, for then vegetation which is suitable for the moths to lay their eggs upon is removed. The earlier the preceding year grasslands to be planted to corn are plowed, the less will be the probability that the cutworm moths will have laid their eggs thereon, and the less, consequently, will be the danger of injury by cutworms the following year.

Late fall and winter plowing of grasslands, although not as effective as early plowing, will destroy many of the hibernating cutworms, as well as such other important corn pests as white grubs, and should be practiced when earlier plowing is impracticable.

Pasturing hogs upon land supposed to harbor cutworms is a beneficial practice, as these animals root up and devour insects of many kinds, including cutworms, in large numbers. Farm poultry, allowed to follow the plow, is of great value.

When cutworms are found to be abundant on corn land, the use of the poisoned bait described on page 10 is recommended. In fields known to be infested, the distribution of this bait should be begun as soon as the corn appears above the ground, so that the cutworms may be eliminated as quickly as possible and the injured hills replanted promptly. During the warmer spring months cutworms do most of their feeding at night and burrow into the soil to the depth of an inch or two during the day, so that the bait usually will be more effective if applied during the late afternoon and early evening hours.

Frequently cutworms migrate to cultivated fields from adjoining grassland, and in such cases the crops can be protected by running a narrow band of the poisoned bait around the edge of the field or along the side nearest the source of infestation.[1]

GRASSHOPPERS.[2]

Grasshoppers are injuriously abundant in various parts of the United States every year. Their ravages, which occur chiefly on alfalfa and the grasses, can be prevented largely by cheap and practical means, especially where vigilance is exercised. These pests may be discovered in their young stages, when it is easy to control them by means of the poisoned baits described below. The more injurious kinds of grasshoppers nearly all live over the winter in the eggs which are placed in the ground by the old grasshoppers in late summer or early fall. The eggs hatch the following spring, usually during the months of May and June in the Northern States. *Every effort should be made to discover the young insects* (fig. 8) *before*

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[1] Further information regarding these pests is contained in Farmers' Bulletin 739, which may be secured free of charge upon application to the Secretary of Agriculture, Washington, D. C.

[2] *Melanoplus* spp., etc.

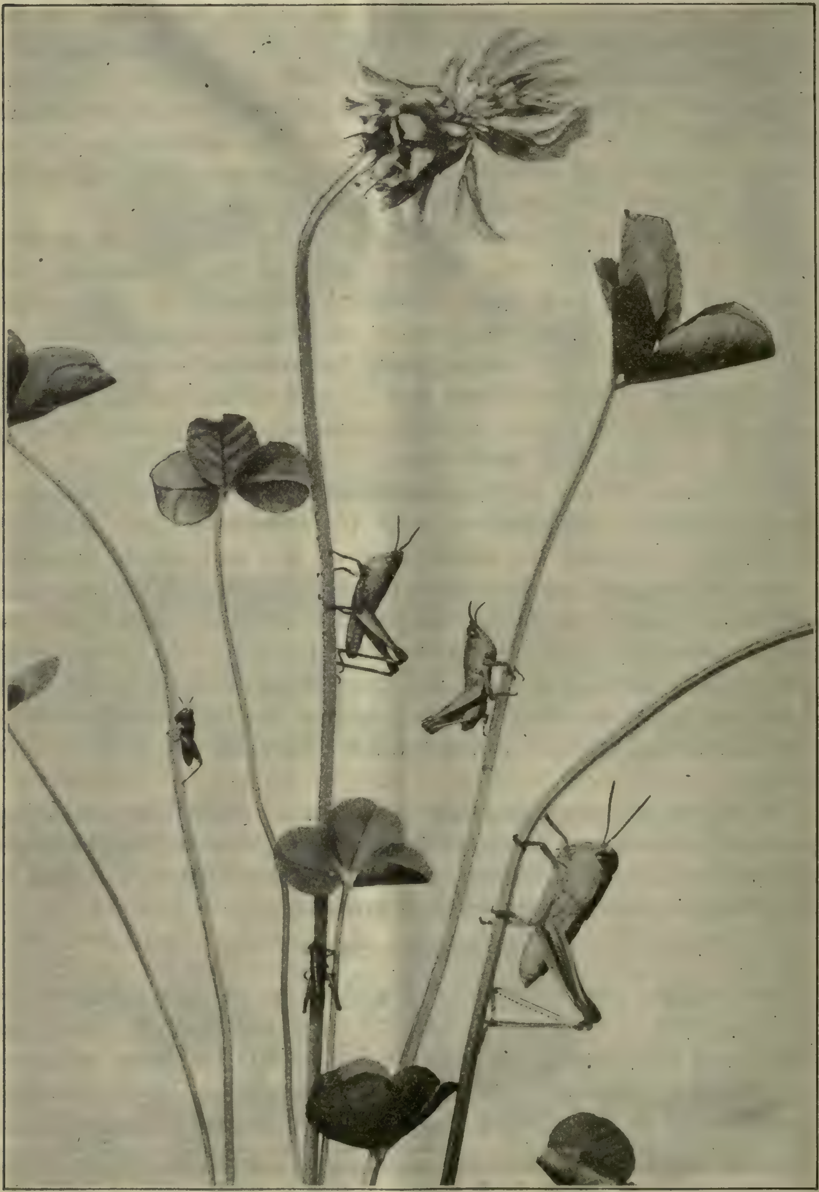

FIG. 8.—Young grasshoppers feeding on clover. In this stage they are easily killed by poisoning.

they have attained any considerable size, when the injury done by them is still very slight, and when they are wingless and easily killed by poisons or mechanical means.

POISONED BAITS FOR GRASSHOPPERS.

The most effective remedies yet discovered for grasshoppers are the following poisoned baits:

The mixture known as the poisoned-bran bait has proved to be a simple, reliable, and cheap method of destroying grasshoppers, and has been applied with signal success throughout many portions of the United States. It is made up as follows: Wheat bran, 25 pounds; Paris green, 1 pound, or powdered arsenate of lead, 2 pounds; lemons or oranges, 6 finely chopped fruits; low-grade molasses, such as refuse from sugar factories, or cattle molasses, known as "black strap," 2 quarts; water, 2 to 3 gallons. The bran and Paris green or arsenate of lead are thoroughly mixed while dry, the fruits are then finely chopped and added, and lastly the molasses and water are poured over the bait and the whole thoroughly kneaded. A coarse-flaked bran is most desirable, although where this can not be obtained easily ordinary middlings or alfalfa meal may be substituted; a low-grade, strong-smelling sirup or molasses, however, is essential to the entire success of the undertaking. Crushed ripe tomatoes, watermelons, or limes may be substituted for the lemons or oranges, if necessary. In California and other semiarid regions water should be added to the bait at the rate of 4 gallons to 25 pounds of bran, as in these climates the bait dries out very rapidly and the extra moisture is necessary in order to attract the grasshoppers.

Another effective bait of similar character is the modified Criddle mixture. This is prepared as follows: Fresh horse droppings, one-half barrel; Paris green, 1 pound, or powdered arsenate of lead, 2 pounds; finely chopped oranges or lemons, 6 to 8 fruits; water sufficient to make a moist but not sloppy mash. This bait must be mixed thoroughly before being distributed, and as most people object to handling this mixture with the bare hands, a pair of cheap rubber gloves may be used for the purpose. Both the poisoned-bran bait and the modified Criddle mixture are distributed over the infested fields by sowing broadcast, either on foot or from a light wagon or buggy.

In applying the poisoned bait in orchards, care must be taken to avoid distributing it close to the trees, because severe injury to fruit trees occasionally results from heavy applications of arsenicals.

Proper time of day for applying the poisoned baits.—The time of day chosen for distributing the poisoned baits has an important bearing upon the results secured. In California and other semiarid regions the bait should be distributed in late afternoon or early evening, just before the grasshoppers ascend the plants on which they usually pass the night. Apparently they are hungry and thirsty at this time and greedily take the bait if it be available. In the moister portions of the country, such as New England and Florida, the bait is best applied in the early morning. *Farmers should not be discouraged if the grasshoppers do not drop dead immediately upon eating the poison, as it usually takes 24 hours or more for the full effect of the baits to become apparent.*[1]

WHITE GRUBS.[2]

White grubs (fig. 9) are the young of the common brown May beetles, or "June beetles," which begin to appear during the latter part of April and continue to be seen in the evening throughout the month of May and even as late as June. These beetles lay their eggs in the ground, preferably in timothy grasslands. The little grubs, upon hatching, feed largely upon decayed vegetable matter in the soil and therefore are not usually detected at this time. On the approach of cold weather they burrow deeply into the soil, where they sleep or hibernate during the winter. When the next spring arrives

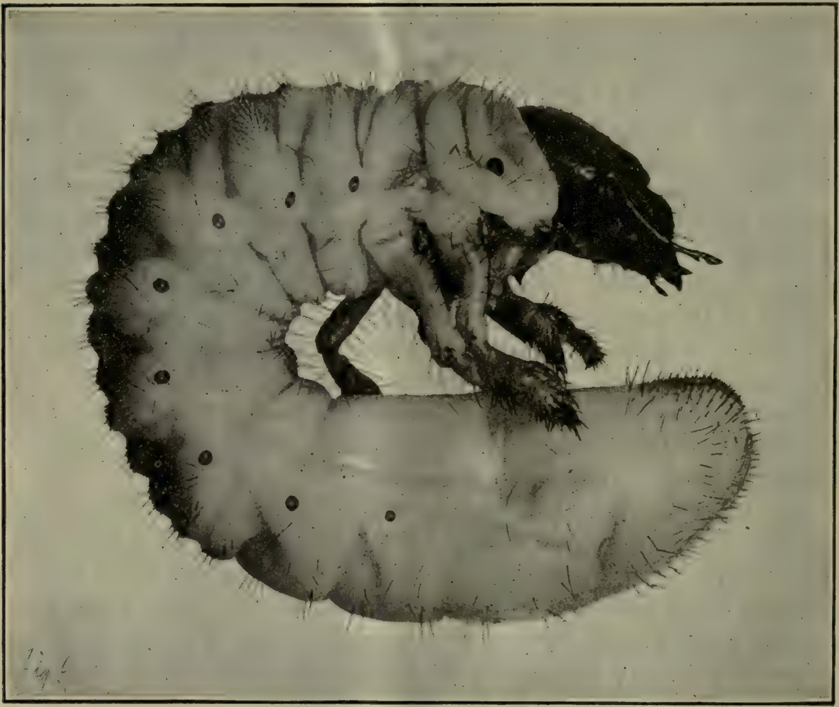

FIG. 9.—A full-grown white grub. Greatly enlarged.

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[1] Further information regarding these pests is contained in Farmers' Bulletin 747, which may be secured free of charge upon application to the Secretary of Agriculture, Washington, D. C.

[2] *Lachnosterna* spp.

they approach the surface of the ground and begin to feed on the roots of grasses, corn, potatoes, strawberries, and seedling trees, especially conifers. They feed ravenously during this second year of their life and by fall are nearly full grown.

If land is found to be heavily infested with the grubs, it should be plowed thoroughly during the summer or early fall, the farm fowls being allowed to follow the plow in order that they may find and eat the grubs as these are brought to the surface. Chickens and other farm poultry are very fond of the insects. Hogs may be turned into such fields with profit, as it is their habit to root out and devour the grubs in great numbers.

On the approach of winter the nearly full-grown grubs once more descend deeply into the ground in order to hibernate until spring, when they come to the surface and feed for a few weeks. During the early summer months, usually in June, they go down deeply for the last time, changing to the resting stage or pupa during August, and then to the beetle in late September. The beetles remain in the ground all winter, coming up the following spring to feed upon the leaves of trees and lay their eggs in the soil for another generation. Thus it takes three years for most of the white grubs to complete their life cycle. Usually, therefore, they are especially abundant in any one region only one year in every three.

WHAT TO DO AT EACH STAGE OF WHITE-GRUB ATTACK.

When heavy flights of May beetles are noticed.—Use lantern traps during the beetles' flights. Spray trees with an arsenical, such as Paris green or arsenate of lead, to poison beetles feeding thereon. Plow grass and small grain land previous to October 1 to destroy young grubs recently hatched from eggs laid by May beetles.

When small grubs are abundant in the fall.—Plow thoroughly previous to October 1. Pasture hogs and allow chickens the run of fields when plowed. Seed such land to small grain or clover for the following year. Do not plant corn or potatoes on such land the following season.

When small grubs are abundant in the spring.—Seed such land to small grain or clover. Do not plant corn or wide-row crop in such land. Put corn, potatoes, field beans, etc., on ground which has been cleanly cultivated the preceding year. Pasture hogs on infested ground, and give chickens the run of fields when plowing and cultivating.

When large grubs are abundant in the fall or spring.—Plow infested land about October 1. Delay planting until the 15th or 20th of May, or a little later if practicable. Ground containing large grubs in spring should be plowed as soon after July 15 as practicable, as indicated below. Pasture hogs in infested fields wherever practicable.

When beetles or pupæ are in the ground in summer.—Plow thoroughly, so as to break clods, any time after July 15, but the sooner after that date the better. Pasture hogs in infested fields.[1]

BILLBUGS.[2]

The billbugs, snout-beetles, or "elephant bugs" (see fig. 10 and illustration on title page), as they are variously termed, are hard-shelled beetles which live normally in sedges, rushes, or the large wild grasses found growing in moist, low ground. Corn planted in river and creek bottoms or other low places, especially in the southern portions of the country, is liable to injury by billbugs. The grubs, or young, of these beetles live inside the stems or roots of plants, and their injuries to corn usually are caused by their eating out the central portion of the stalk, thereby stunting and seriously injuring the corn plants. (See fig. 11.) The adult beetles also injure the corn, for they puncture the growing point or "bud" of the plant.

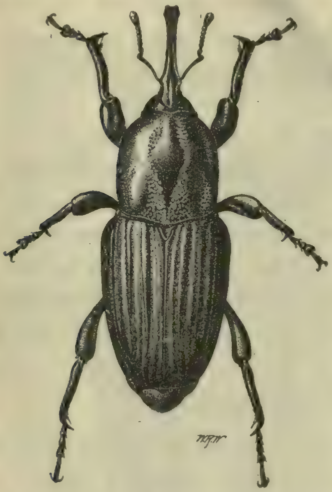

FIG. 10.—The maize billbug (*Sphenophorus maidis*): Adult, four times natural size.

REMEDIES FOR BILLBUGS.

Some kinds of billbugs are eliminated easily by rotation of crops. Corn should not be followed by corn in the Atlantic Coastal Plain region of the South, but may be alternated with cotton, on which the billbugs can not live. *Land infested with these insects should always be plowed in the late summer or early fall*, for thus the winter quarters of the bugs are broken up. The immediate destruction of all sedges, rushes, chufa, or large swamp-inhabiting grasses in land intended to be planted to corn is especially necessary, as these plants are the natural food of the billbugs, and the insects can not be eliminated unless this is done.

CORN ROOT-APHIS.[3]

The corn root-aphis (fig. 12) attacks the roots of corn throughout the States east of the Rocky Mountains, especially in those States

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[1] Further information regarding these pests is contained in Farmers' Bulletin 543, which may be obtained free of charge upon application to the Secretary of Agriculture, Washington, D. C.

[2] *Sphenophorus* spp. The species illustrated on the title-page is *Sphenophorus aequalis* Gyll.

[3] *Aphis maidi-radicis* Forbes.

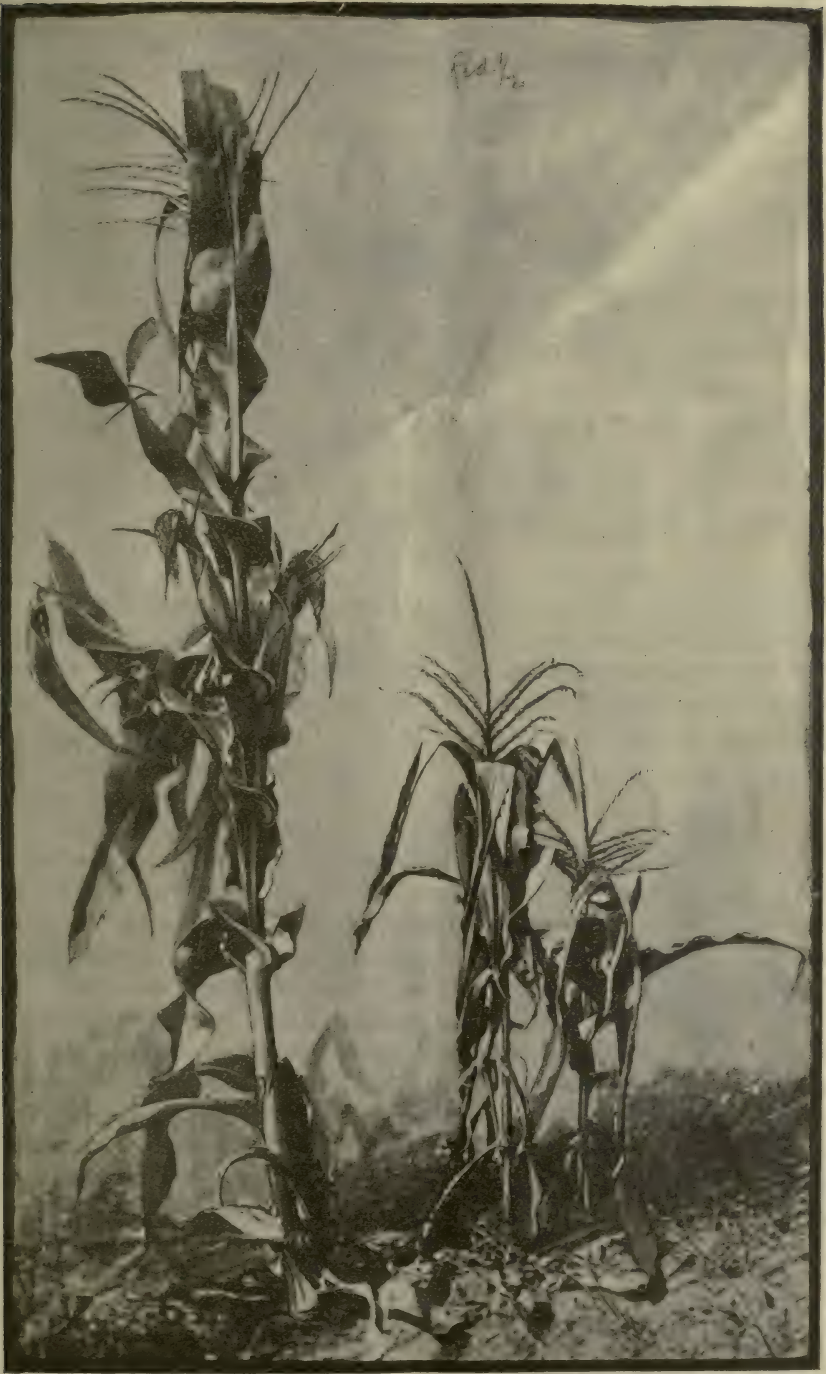

FIG. 11.—Corn plants showing effects of feeding of maize billbug in the field. Plant at left not attacked, the two at right attacked by larvæ.

within the main corn belt of the country, but also in the South Atlantic States. Since it passes almost its entire life underground, its presence frequently is not suspected. It is a small, stout, soft-bodied, whitish-looking insect and may be discovered in infested fields by pulling up the unhealthy corn plant and closely examining the roots and surrounding soil. This kind of aphis depends entirely upon the services of a small brown ant, sometimes called the cornfield ant, in order to secure its food and the means of surviving the winter, and the presence of an unusual number of brown ants in cornfields may indicate an infestation of the corn root-aphis. The eggs of the insect are laid by a wingless female aphis (fig. 13) which develops only in the fall of the year. The ants carry the aphis eggs into their nests, caring for them all winter long, and in the spring when the eggs hatch the young aphids are carried out and placed in contact with the roots of certain wild plants such as smartweed. If corn is then planted in such infested places, the ants transfer the aphids to the roots of the corn plants, where they continue to live upon the sap, thereby robbing the corn of its nourishment and often causing a heavy loss to the crop.

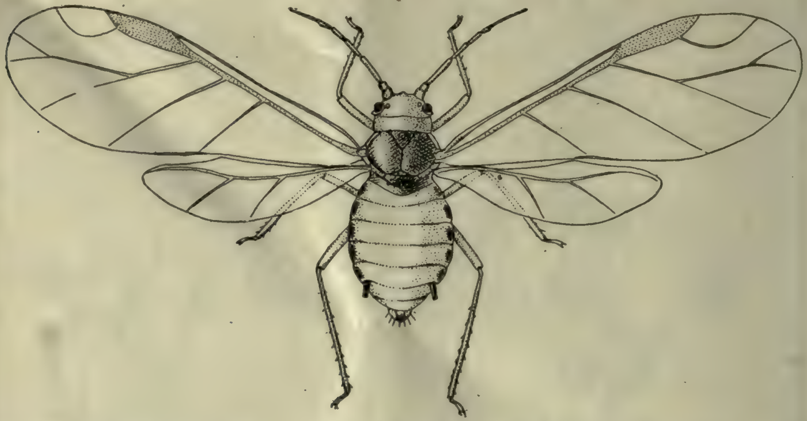

FIG. 12.—The corn root-aphis (*Aphis maidi-radicis*) : Winged, viviparous female. Greatly enlarged.

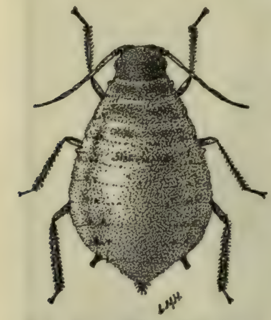

FIG. 13.—The corn root-aphis: Egg-laying female.

CULTURAL PRACTICES FOR THE CORN-ROOT APHIS.

Stir the soil thoroughly previous to planting. The object of this procedure is to disturb the ant colonies and scatter and kill the aphids so as to enable the plants to make a substantial growth before the ant and aphid colonies can become reestablished, and also to prevent the growth of weeds upon which the aphids live, making it necessary for the ants to carry the surviving aphids to new fields. If infested fields are to be replanted to corn, plow them to a depth of 6½ or 7 inches in the spring after March 15. Follow this with three or four diskings to a depth of 4 or 5 inches with a 16 or 20 inch disk, the number of diskings and the intervals between them varying according to the length of the period between plowing and planting. When it is necessary to replant early injured corn, plow the field deeply and thoroughly and then give three or four deep diskings at intervals of two or three days. These practices necessarily involve additional labor, but they prevent root-aphis injury and also put the field in much better physical condition. Plowing in the fall before the ant colonies go below the plow line is sometimes as useful as spring plowing, but if warm weather follows, the ants may reconstruct their nests and reassemble the aphids so that replowing in spring will be necessary; but whether the field be plowed in the fall or the spring, the spring diskings are essential.

Early fall plowing, followed by frequent deep diskings in fields damaged by the root aphis that season, is a good practice from the standpoint of community control as well as for the personal benefit derived, because the plowing disturbs the ant colonies, kills many of the aphids, and destroys the weeds upon which they live, and disking prevents the recolonization of ants and prevents the growth of weeds, resulting in a significant reduction in the number of aphid eggs to carry the insect through the winter.

REPELLENTS FOR THE CORN-ROOT APHIS.

Where it is impossible to practice one of the foregoing measures, repellents may be used to advantage. The object is to repel the ants by the use of an odorous substance offensive to them, thus preventing them from colonizing the aphids on the corn roots or driving them from the treated field. These materials destroy neither the ants nor the aphids but tend to drive away the ants, the presence of which is essential to the life of the aphids. Oil of tansy, tincture of asafetida, oil of sassafras, anise oil, kerosene, and oil of lemon are useful for this purpose, one of these materials being mixed with a chemical fertilizer, such as bone meal, and applied by means of a planter equipped with a fertilizer attachment. They should not be applied directly to the seed, as such treatment may injure it, especially if the season be wet. One-fourth of a pound of oil of tansy should be diluted with 2 quarts of alcohol and 1 quart of water, 2 pints of asafetida should be diluted with 1½ gallons of water, and either repellent thus diluted should be added to 100 pounds of bone meal, this amount being sufficient for an acre.

WIREWORMS.

Wireworms (see fig. 14) are especially destructive to seed corn in the ground and to the young corn and wheat plants. They work entirely underground and are among the most difficult to control of all the insect foes that afflict the farmer. Much may be done, however, to lessen their ravages by careful tillage, drainage, proper rotation of crops, etc., as will be explained.

Wireworms are the young of the common snapping beetles, or click beetles, and the worms are yellowish or brownish, highly polished and slippery to the touch. They move actively and disappear rapidly when brought to the surface by the plow or spade. The eggs are laid in the ground, usually in sod lands, where the young worms are hatched. It takes three years for most kinds of wireworms to get their full growth and to become beetles.

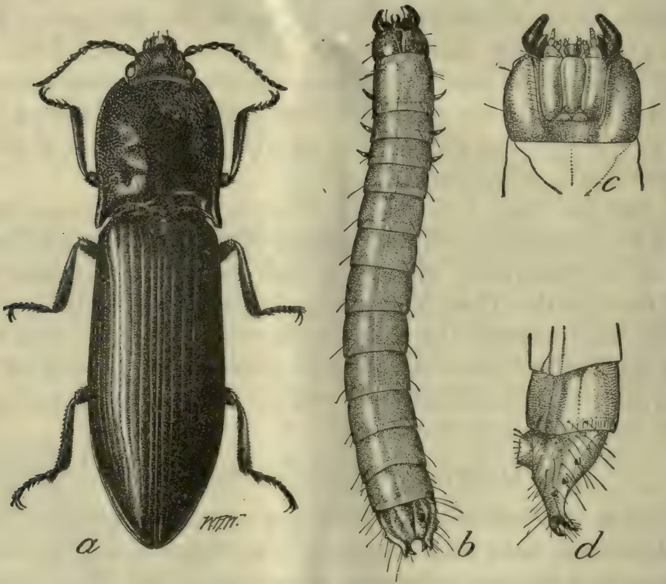

Fig. 14.—The dry-land wireworm (*Corymbites noxius*): *a*, Adult; *b*, larva; *c*, under surface of head of larva; *d*, side of last segment of larva. *a*, *b*, Enlarged; *c*, *d*, more enlarged.

REMEDIES FOR WIREWORMS.

The most successful methods for the control of wireworms are cultural in nature, it having been found impossible, or at least impracticable, to poison them by any known means.

Where it is proposed to plant sod land to corn the following year, to prevent wireworm injury the land should be plowed immediately after the first hay cutting, usually early in July, and should be cultivated deeply during the remainder of the summer.

Land already in corn which is badly infested should be cultivated deeply, even at the risk of slightly root pruning the corn. This should be continued as long as the corn can be cultivated, and as soon as the crop is removed the field should be tilled thoroughly before it is sown to wheat.

In regions where wheat is seeded down for hay, any treatment of infested fields is precluded. Where the wheat is not followed by seeding to other crops, the fields should be plowed as soon as the wheat is harvested. This kills the worms by destroying their food supply and preventing them from preparing suitable sleeping quarters for the winter.

A thorough preparation of corn land and a liberal use of barnyard manure or other fertilizer is recommended, and a vigorous stand may be produced sometimes in spite of the wireworms by such treatment. Wherever practicable the interposing of crops not severely attacked by wireworms, such as field peas or buckwheat, between sod and corn tends materially to reduce the number of wireworms in the soil.

Some kinds of wireworms live only in badly drained land, and for this reason thorough tile draining of such fields is often very beneficial, especially where the general condition of the fields is improved by proper applications of lime and thorough cultivation.

In the Northwest and northern Middle West the dry-land wireworm (fig. 14) sometimes is very injurious. The following methods have been found to be valuable in the elimination of this pest: (1) Disk or drag harrow the summer fallow as early as possible in the spring in order to produce a dust mulch and thereby conserve the accumulated winter moisture; (2) continue the disking as often as is necessary in order to maintain the mulch and keep down the weeds; (3) plow the summer fallow in July or early in August and immediately drag; (4) plow the stubble as soon as the crop is removed.[1]

Do not plant grain, and especially corn, on freshly broken sod land if this can be avoided. To do so exposes it to almost certain injury by wireworms, cutworms, and white grubs. Plant such land first to soy beans, cowpeas, clover, alfalfa, or buckwheat, afterwards rotating to grain. The growing of any one kind of grain on the same land continuously is sure to result in damage from insect pests, and is bad agricultural practice. Adopt a good system of crop rotation suitable to your particular region. If you do not know the most approved system of rotation for your locality, ask your county agricultural agent or State experiment station for advice.

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[1] Farmers' Bulletin 725 contains additional information on wireworms and will be mailed free of charge on application to the Secretary of Agriculture, Washington, D. C.

POINTS TO REMEMBER.

(1) Watch the grain crops carefully for the earliest indications of insect outbreaks. Make a daily survey of the fields during the most active growing season, if possible.

(2) If an outbreak of any insect foe is discovered, apply promptly the remedies recommended in the foregoing pages.

(3) If in doubt as to the identity of the pest, promptly send a specimen, inclosed in a tight tin box, to your county agricultural agent, State experiment station, or nearest Federal entomological field station, accompanied by a request for information regarding it.

(4) Keep on hand at least a small supply of the standard insecticide preparations, such as Paris green, lime, and arsenate of lead. Very often the delay caused by the fact that these preparations are not immediately available is fatal to the crop attacked.

(5) Report serious outbreaks of insects to one of the authorities mentioned above. Federal entomological field stations charged with the investigation of cereal and forage insects are located at the following places:

Arizona—Tempe.
California—Martinez.
Indiana—West Lafayette.
Iowa—Sioux City.
Kansas—Wellington.
Maryland—Hagerstown.
Missouri—Charleston.
Ohio—Wakeman.
Oregon—Forest Grove.
Pennsylvania—Carlisle.
South Carolina—Columbia.
Tennessee—Knoxville.
Texas—San Antonio.
Utah—Salt Lake City.
Virginia—Charlottesville.

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IMPORTANT PECAN INSECTS AND THEIR CONTROL

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FARMERS' BULLETIN 843

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C. September, 1917

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THE PECAN has a number of important insect enemies of more or less extended distribution. Some of these injure the nuts, others the foliage and shoots, and still others the trunk and branches. Owing to the wide diversity in their methods of attack, no general directions for the control of these pests can be given, and in the adoption of remedial measures the peculiar habits of each species must be considered. This bulletin describes the more important insects that injure pecan and suggests the methods that should be followed to avert damage.

IMPORTANT PECAN INSECTS AND THEIR CONTROL.

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THE pecan industry in the South has developed rapidly. This development, however, has been accompanied by an important increase in the number and destructiveness of the insects attacking the crop. The loss to pecan growers from insect attacks has amounted to hundreds of thousands of dollars annually, and in the absence of preventive measures it is certain to increase. The present bulletin gives results of studies of the more important pecan insects by the Bureau of Entomology.

INSECTS INJURING THE NUTS.

THE PECAN NUT CASE-BEARER.[1]

The pecan nut case-bearer, in its larval or "worm" stage, attacks for the most part the immature nuts and is capable of reducing the crop greatly. During May, shortly after the nuts have set and when they are not much larger than garden peas, the larvæ will be found boring into them, and at the point of attack casting out pellets of frass, or borings, which are held together by means of fine silken threads that form a short silk-lined tube. Nuts injured by this insect always show the characteristic mass of frass protruding from the place where the larvæ gained entrance, which is invariably near the junction of the base of the nut with the stem. During the early part of the season, when the nuts are small, one larva will often destroy several nuts before attaining its full growth.

This nut case-bearer, as well as another species[2] that attacks the pecan in a somewhat similar way, has often been reported as destroying from one-third to three-fourths of the total crop of wild pecans

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[1] *Acrobasis hebescella* Hulst.

[2] *Acrobasis caryivorella* Rag.

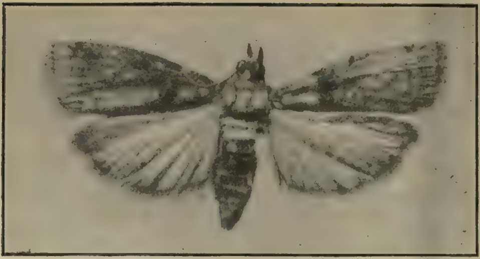

FIG. 1.—The pecan nut case-bearer (*Acrobasis hebescella*): Moth. Much enlarged.

in various localities in Texas. Until very recently this insect has not been reported in the cultivated orchards east of Texas, but within the last few years it has become a serious pest in some localities in Florida, Georgia, Alabama, Mississippi, and Louisiana. It would seem that this species is extending its range of destructiveness, and in view of the large acreage of pecan orchards now bearing or coming into bearing, sooner or later it probably will prove a most formidable pest throughout the greater part of the pecan belt.

DESCRIPTION.

In the course of development the pecan nut case-bearer passes through four distinct stages, namely, the egg, the larva or "worm," the pupa or resting stage, and the adult or moth. The grayish-black moth (fig. 1) has a wing spread of about three-fourths of an inch. The head and thorax are brownish and the abdomen is yellowish gray. The forewings are grayish black and each has a ridge or tuft of long black scales extending across it near the basal end. The hindwings are much brighter than the forewings and without any conspicuous markings.

The egg is irregularly oval in outline. When first laid it is white, with a greenish tinge, but as incubation proceeds it becomes pinkish or reddish. It is iridescent in some lights.

The full-grown larva, or caterpillar (fig. 2, at right), is about one-half inch in length, and the general color of the body is dirty olive green. The skin of the body is wrinkled into folds and is sparsely covered with inconspicuous hairs. The head and mouth parts are dark brown, and the cervical shield, or neck, is pale brown, bisected by an inconspicuous whitish-yellow area.

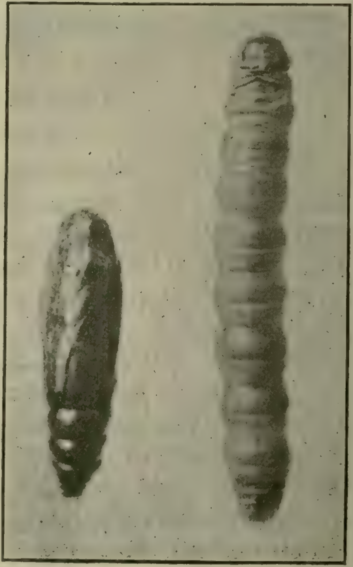

FIG. 2.—The pecan nut case-bearer: Pupa at left, larva at right. Much enlarged.

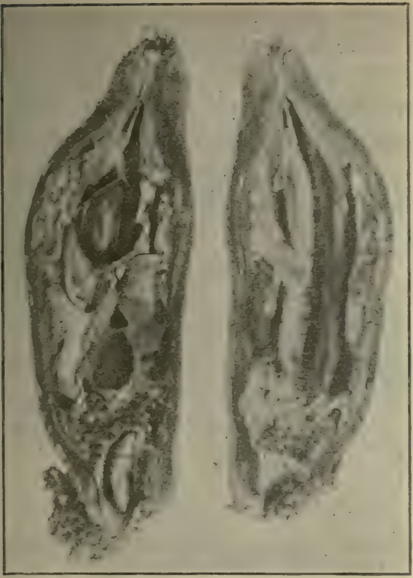

FIG. 3.—The pecan nut case-bearer: Place of pupation in pecan nut.

The pupa (fig. 2, at left) is brown and of the usual form. It is rounded at the posterior end, and here it bears a cluster of small hooked spines. Pupation always takes place in the infested nut or shoot (fig. 3), and upon emergence of the moth the pupal skin is not left protruding as it is in the case of certain other insects.

SEASONAL HISTORY AND HABITS.

This insect has three distinct generations during the year. The larvæ which have lived through the winter become active at the time when the foliage appears in the spring and they attack the young and tender shoots, in which they tunnel by eating out the interior, leaving the outside intact (fig. 4). The moths of the first generation, which are the progeny of the moths developing from the hibernating larvæ, make their appearance from May 7 to 24 and soon after emergence lay their eggs. The eggs are invariably deposited on the calyx end of the nut, and usually at or near the base of the calyx lobes. From 5 to 7 days are required for the eggs to hatch. The larva, as soon as it gnaws its way out of the eggshell, crawls to the base of the young nuts, where it commences feeding. It bores its way into the nuts (fig. 5) and as it feeds it webs together, by means of silken threads, particles of frass and excrement which assume somewhat the shape of a tube smoothly lined with grayish white silk. These tubelike masses of frass are readily seen extruding from the base of infested nuts (figs 5 and 6). The larva period lasts from 22 to 29 days and the pupa period from 9 to 13 days.

Most moths of the second generation emerge from the middle of June up to the first week of July. It was determined that all moths in a large series under observation actually emerged during the period from June 11 to July 15, but the maximum emergence occurred during the last week in June. Second-brood larvæ attack the

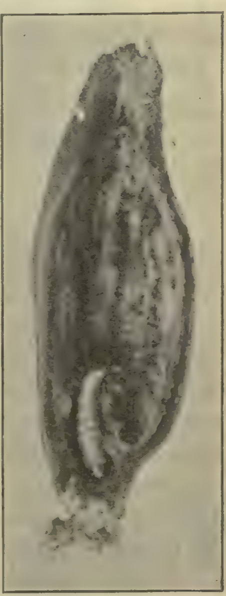

FIG. 4.—The pecan nut case-bearer: Young pecan nut infested by larva.

nuts in the same manner as those of the first generation, but usually the injury to the nut crop by these larvæ is not so great.

Most of the moths of the third generation appear during the first three weeks in August. The larvæ from this generation do little or no damage to the nuts, which usually are beginning to harden at this time, and they seem to prefer to feed in the petioles or tender shoots. The winter is passed as immature larvæ in cocoons or hibernacula, which are formed around the buds. In rearing cages it was observed that larvæ which hatched from eggs laid by third-brood moths usually fed very little before constructing winter cases around the buds. It was noticed, however, that a very few larvæ fed extensively and transformed to pupæ, from which moths emerged during the last part of September, thus indicating a fourth generation. But observations in pecan orchards failed to show any indications of a fourth generation.

CONTROL MEASURES.

The pecan nut case-bearer is already an established pest in certain important pecan-growing sections, and because of its increasing destructiveness certain experiments have been conducted for the determination of positive means of control. During the seasons of 1915 and 1916 series of spraying experiments were conducted in a pecan orchard at Monticello, Fla. All sprayed plats were treated with 1 pound of powdered arsenate of lead plus 3 pounds of slaked stone lime to each 50 gallons of water. In all cases the material was applied with a well-equipped gasoline-power outfit, and a pressure varying from 150 to 200 pounds was maintained.

The results of spraying experiments for 1915 are shown in Table 1.

TABLE 1.—*Spraying experiments against the pecan nut case-bearer, Monticello, Fla., 1915.*

Plat No.	Number of count trees.	Date of spraying.	Total nuts for season.	Number of nuts infested.	Number of sound nuts.	Per cent of sound nuts.
I	5	May 15 and 27 and June 24	3,559	748	2,811	78.98
II	5	May 15 and June 24	3,915	756	3,159	80.68
III	5	May 27 and June 25	4,366	1,125	3,241	74.23
IV	5	Check, unsprayed	1,923	779	1,144	59.49

It will be seen that Plat I, which received three applications, gave 78.98 per cent of sound nuts, and showed a benefit of 19.49 per cent over the check or unsprayed plat, which had only 59.49 per cent of sound nuts. Plat II, which received only two applications, yielded a somewhat greater percentage of sound nuts, while Plat III, which had only one application, yielded 74.23 per cent of sound nuts. The benefit for each plat over the check plat is shown in percentages as follows: Plat I, 19.49; Plat II, 21.19; and Plat III, 14.74. It is worthy of mention that out of the 40.51 per cent of infested nuts on

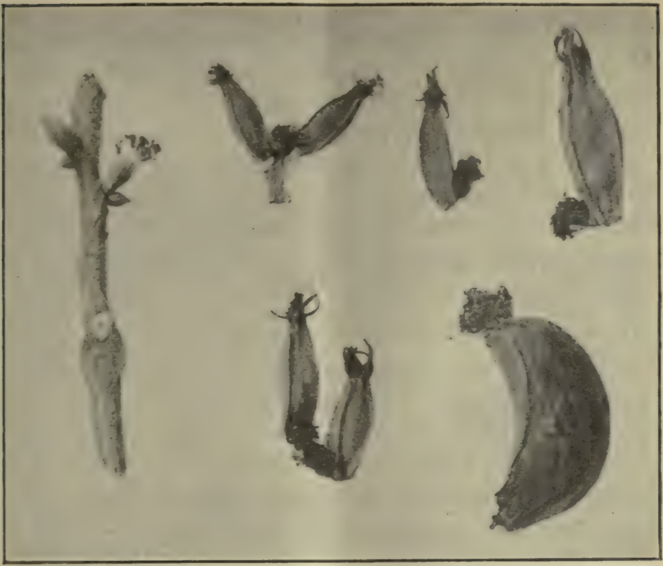

FIG. 5.—The pecan nut case-bearer: Young pecans showing injury by larva.

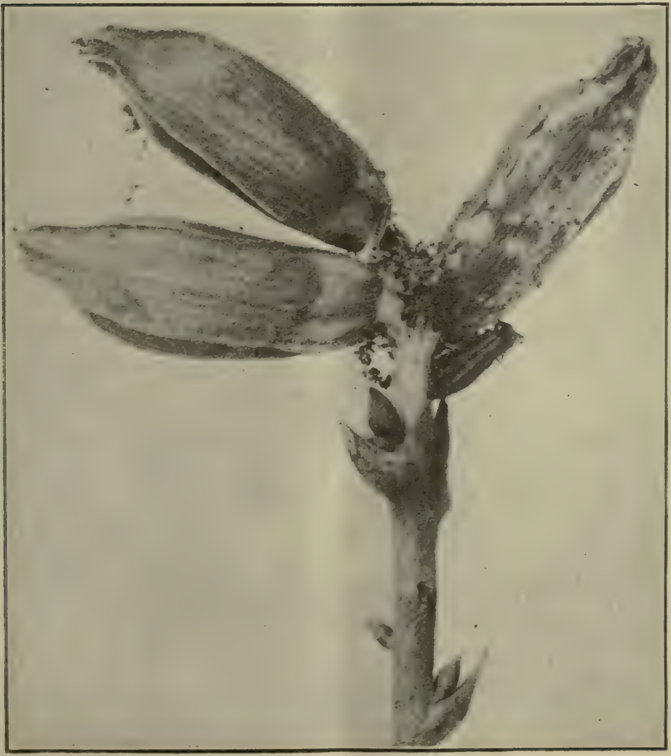

FIG. 6.—The pecan nut case-bearer: Cluster of infested young pecan nuts.

the unsprayed plat (Plat IV) the injury by the first brood of larvæ amounted to 29.90 per cent, while the second-brood infestation was only 10.61 per cent, thus showing the proportional attacks on the nut crop by the first and second broods of larvæ.

The results of the spraying experiments for the season of 1916 are shown in Tables 2 and 3. The two series of experiments, as outlined in these tables, were conducted in the same orchard, but a distance of fully one-fourth of a mile separated them.

TABLE 2.—*Spraying experiments against the pecan nut case-bearer, Monticello, Fla., 1916.*

Plat No.	Number of count trees.	Date of spraying.	Total nuts for season.	Number of nuts infested.	Number of sound nuts.	Per cent of sound nuts.
I	5	May 12 and 24 and June 24	3,929	190	3,739	95.16
II	5	May 12 and 24	4,608	302	4,306	93.44
III	5	May 12 and June 20	5,522	407	5,115	92.62
IV	5	Check, unsprayed	3,352	581	2,771	82.67

As will be noted in Table 2, the best results were obtained on Plat I, which received three applications, there being 95.16 per cent of sound nuts. The infestation in the unsprayed plat (IV), however, was not severe, since 82.66 per cent of the nut crop came through in sound condition. The actual percentage of infestation in this plat was 17.33 of the total crop, 12.14 being due to the first-brood larvæ. Plats II and III showed 93.44 and 92.62 per cent of sound nuts, respectively. The benefit to each sprayed plat over the check (Plat IV) is given in percentages as follows: Plat I, 12.49; Plat II, 10.77; and Plat III, 9.95.

TABLE 3.—*Spraying experiments against the pecan nut case-bearer, Monticello, Fla., 1916.*

Plat No.	Number of count trees.	Date of spraying.	Total nuts for season.	Number of nuts infested.	Number of sound nuts.	Per cent of sound nuts.
V	5	May 12	2,461	546	1,915	77.81
VI	5	Check, unsprayed	1,569	380	1,189	75.78
VII	2	May 24	474	77	397	83.75
VIII	2	May 12 and 24	690	70	620	89.85

As will be noted in Table 3, Plat V, which received one application on May 12, gave only 77.81 per cent of sound nuts, as compared with 75.78 per cent of sound nuts on the unsprayed plat (VI), showing a benefit of only 2.03 per cent from the treatment. Plat VII, which received one application on May 24, showed 83.75 per cent of sound nuts, while Plat VIII showed a percentage of 89.85 of sound nuts. The benefit to each sprayed plat over the check (Plat VI) is shown in the following percentages: Plat V, 2.03; Plat VII, 7.97; and Plat VIII, 14.07.

In working out control measures for this pest, it has been determined that the spray applications must be made during very limited periods in order that satisfactory results may be obtained. In spraying for this species timeliness and thoroughness of application are two essentials that must be observed most faithfully, for even the slightest delay or carelessness in applying the spray is likely to result in very disappointing returns from the treatment. Since the eggs of the first brood of moths are hatching for a period of fully two weeks, and as the nuts are growing very rapidly at this time, it is necessary to make two applications for the protection of nuts against infestation by the first-brood larvæ, which, as has been stated before, invariably cause the most damage to the crop. It has been found necessary to spray once for the second-brood larvæ, which usually begin to bore into the nuts shortly after the middle of June.

RECOMMENDATIONS.

Investigations conducted so far show that the best method of control against the pecan nut case-bearer is spraying with arsenate of lead. The arsenate of lead should be used at the rate of 1 pound of the powdered form or 2 pounds of the paste form to each 50 gallons of water, to which should be added the milk of lime from 3 pounds of slaked lime. Three applications will be required and should be made at the following periods:

First.—Shortly after the nuts have set, at which time they are about the size of garden peas.

Second.—One week or ten days after the first application.

Third.—Four or five weeks after the second application.

The date for the first application at Monticello, Fla., during the season of 1916, was found to be May 12. It should be borne in mind, however, that the time of spraying probably will vary somewhat according to latitude and for different seasons.

THE PECAN SHUCKWORM.[1]

A rather slender, white larva or caterpillar (fig. 7, at right), about three-eighths of an inch in length, is found mining the shucks of pecan and hickory during the autumn months. This caterpillar is referred to commonly as the pecan or hickory shuckworm, or huskworm, and for the discussion of the insect in this bulletin the name pecan shuckworm is employed. The mining or tunneling of the shucks often results in the improper development of the nut kernels and

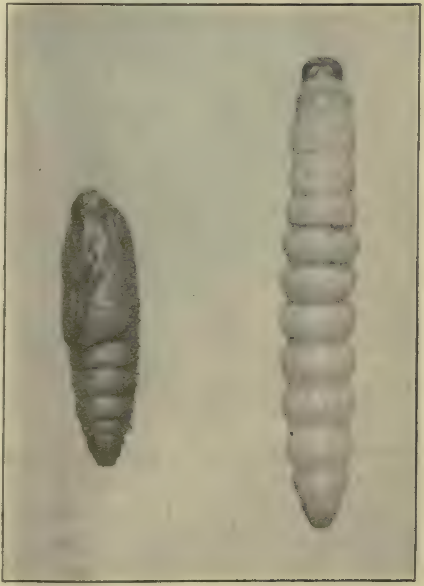

FIG. 7.—The pecan shuckworm (*Laspeyresia caryana*): Pupa at left, larva at right. Enlarged.

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[1] *Laspeyresia caryana* Fitch.

prevents the natural separation of the shucks from the nutshells. Nuts attacked by the shuckworm during the late fall usually will mature in fairly good condition for the market, but if the injury takes place early it will result in inferior or unmarketable fruit. Sooty trails on the shell of the nuts often result from the attack of the larvæ, the nuts sometimes being so discolored as to lessen their market value. The damage is not restricted entirely to the matured nuts, for during the summer the early generations of larvæ attack the small, green nuts by eating out the interior, causing them to fall to the ground. (Fig. 8.) Injury of this type is not so noticeable or so widespread as that which takes place in the fall, but it plays no small part in the reduction of the nut crop.

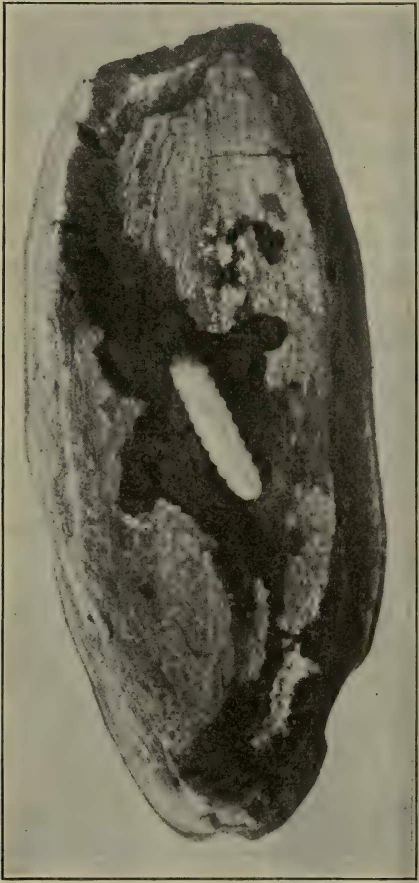

FIG. 8.—The pecan shuckworm: Larva in shuck of nearly matured pecan nut. Enlarged.

Besides attacking the pecan, this insect feeds upon the nuts of the various species of hickory, where the injury it does is precisely like that done to the pecan, except that the destruction of the small, green nuts seems to be greater. Occasionally the larvæ will be found subsisting on the galls formed by a certain species of aphid.[1]

Before nuts have set on pecan trees larvæ sometimes will be found boring into and tunneling the succulent shoots, but this form of injury is very uncommon, as this species is primarily a nut-infesting insect.

DESCRIPTION.

This insect passes through four stages: The egg, the larva, the pupa, and the adult or moth. The moth of the shuckworm (fig. 9) is smoky black, mixed with iridescent bluish and purplish tinges, and the forewings have a series of short, yellowish streaks across their front margins. The moths are rather variable in size, but the maximum expanse of wings is rarely more than three-fifths of an inch. Because of their protective coloration the moths are seldom observed in pecan orchards, even by keen observers.

The egg is small, whitish, and more or less oval, and under high magnification its surface is seen to be wrinkled. The eggs are deposited singly on either the nuts or the foliage. During the summer months the average time of hatching is about 5 days, but the time may vary considerably, depending upon the weather conditions.

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[1] *Phylloxera caryaecaulis* Fitch.

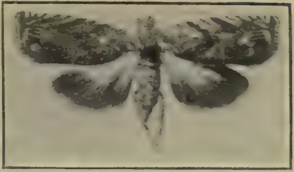

FIG. 9.—The pecan shuckworm: Moth. Enlarged.

The larva upon hatching is a very small, whitish, 16-footed caterpillar, but when full grown it is about three-eighths of an inch in length and has a creamy white body and light brown head (fig. 7, at right). It is in the larval stage that injury is done to the nuts.

The pupa (fig. 7, at left), which is brownish, is always found within the infested nut. Before transformation to the pupa stage the larva prepares a small silk-lined cocoon, and cuts a small circular hole on the outside of the shuck, which facilitates the issuing of the moth. Upon the emergence of the moth the pupal skin is extended a short distance through the circular cut (see fig. 10), the lid of which remains attached to the nut in a sort of trap-door arrangement.

SEASONAL HISTORY AND HABITS.

The number of broods of the pecan shuckworm probably will be found to vary from one to three for the country as a whole. In the extreme southern portion of its destructive range apparently three generations occur each year, but in the Northern States, where the insect subsists on the various species of hickory, there is perhaps only one generation. The moths, which develop from larvæ that spend the winter in the fallen pecan or hickory shucks, begin to appear in northern Florida as early as the middle of February and continue to emerge until the latter part of April, the spring emer-

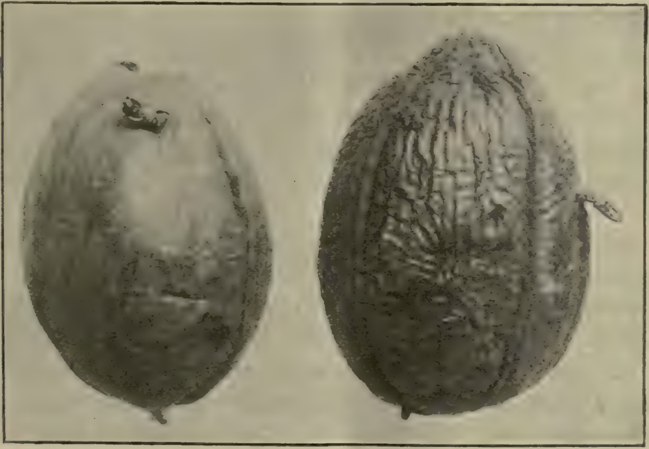

FIG. 10.—The pecan shuckworm: Pupal skins protruding from shucks of pecan nuts.

gence thus covering a period of more than two months. It has been determined, however, that the maximum emergence of moths occurs during the last two weeks of March. Extensive observations have shown that the vast majority of moths come forth before the appearance of the pecan foliage and nuts, and this apparently accounts for the extremely small numbers of first-brood larvæ that attack the pecan trees. The development of the foliage and nuts of the pignut[1] and white hickory[2] is much earlier in the spring than that of the pecan, and it seems that the emergence of moths is timed for these host plants. In this connection it is interesting to note that considerable damage always is done to the very small hickory nuts by the first brood of larvæ, while the very small pecan nuts seem to escape such injury. Some first-brood larvæ will be found attacking the tender shoots of pecan, but the apparent reason for the immunity from attack of the recently set pecan nuts is the fact that the emergence of moths does not coincide very well with the development of the nut. Since the moths are capable of flying some distance, it is likely that for the purpose of egg-laying some of those emerging from pecan shucks during the spring succeed in reaching hickory trees growing adjacent to pecan orchards.

The moths deposit their eggs on the young nuts or foliage, and during the summer months the period of incubation lasts about 5 days. Upon hatching the larvæ gnaw their way into the nuts by making a pinhole entrance, and proceed to mine the shucks in the nearly matured fruit, but some larvæ bore into the interior of the green nuts and cause them to drop to the ground.

During the spring and summer the larvæ usually feed from 3 to 4 weeks, and transform to pupæ within the green nuts or the shucks of the matured fruits. The length of the pupa stage is found to range from 9 to 45 days. During the summer months it lasts about 11 days, while most of the pupæ from overwintering larvæ transform to moths in 18 days, although some few moths do not issue for a considerably longer period. The pupation of the overwintering larvæ occurs from about the first of February until the middle of April.

As stated before, the larvæ of the first brood feed for the most part on the small hickory nuts, but during the last days of June and through July and August, although continuing their depredations on the hickories, the larvæ will be found attacking the green pecan nuts. The first and second broods of larvæ destroy the interior of the nuts and invariably cause them to drop. The last brood of larvæ, which attacks the nearly matured nuts with hard shells (fig. 11), feeds only on the shucks, in which they mine and attain full growth before the advent of cold weather. They pass the winter as larvæ in the shucks on the ground or in shucks that remain on the trees.

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[1] *Hicoria glabra* Britt.

[2] *Hicoria alba* Britt.

CONTROL MEASURES.

It is impracticable to spray for the control of this pest, because of the great difficulty encountered in destroying the larvæ before they enter the nuts or shucks. It will be found impossible also to destroy the larvæ and pupæ, or prevent the emergence of moths, by plowing under the shucks during the fall or winter months, as experiments have shown that the burial of infested shucks as deep as 6 inches during the late fall did not prevent many moths from emerging the following spring.

Since the insect passes the winter as larvæ in the shucks on the ground, it seems that the best method of control is to gather and destroy all shucks, and this should be done immediately after the harvesting of the nut crop, or not later than the middle of February. By the adoption of this method the majority of the larvæ will be killed and thus the infestation of the pecan orchard during the ensuing season will be prevented.

Hickory trees growing adjacent to pecan orchards will prove always a source of infestation by this pest as well as other injurious insects. It would seem, therefore, that the cutting down of hickory trees in the immediate vicinity of the orchards would be a very good procedure for pecan growers.

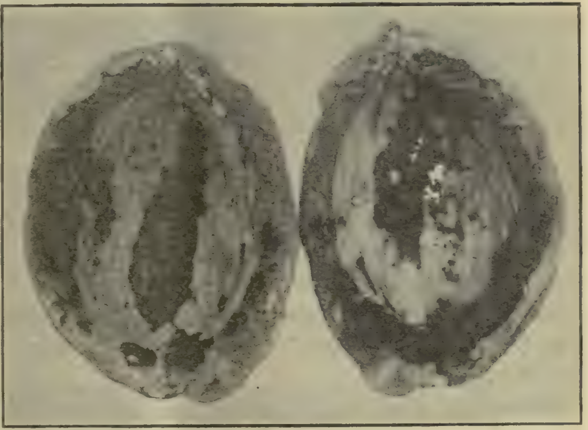

FIG. 11.—The pecan shuckworm: Larval injury to matured pecan nuts.

THE PECAN WEEVIL.[1]

The pecan weevil, often termed the hickory-nut weevil, has long been known in some sections as a serious drawback to the successful culture of pecan nuts as well as hickory nuts. The greatest damage reported has been on the wild pecans in Texas, but this insect is also a formidable pest in certain restricted localities in Georgia, Mississippi, and Louisiana, where the so-called paper-shell pecans are grown on a large scale. The injury by this weevil is recognized readily by the circular holes in the nutshells (fig. 12), which are made by the grubs in leaving the nuts to enter the ground for hibernation and subsequent pupation. One grower in middle Georgia reported that 90 per cent of his Stuart pecans and 15 per cent of the Schley variety were injured by this insect, but the orchard in question was adjacent to a 250-acre woodland containing many native hickory trees the nuts of which were infested severely. No doubt the serious infestation of the nut crop in this orchard was in a large measure attributable to the close proximity of hickory trees. Another grower in Georgia reported extensive damage to Rome and Stuart varieties of pecan, and in one locality in Louisiana this weevil is reported to have caused a loss of 65 per cent of the pecan yield.

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[1] *Balaninus caryae* Horn.

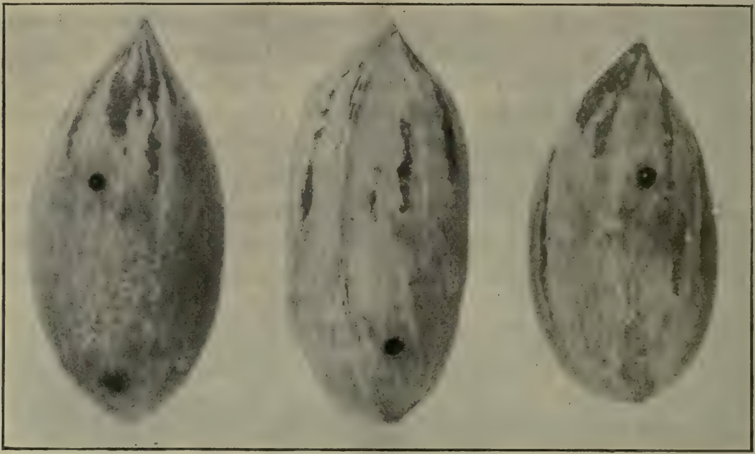

FIG. 12.—The pecan weevil (*Balaninus caryae*): Exit holes of larvæ in pecan nuts.

Although this insect is distributed very widely throughout the country, occurring on both the wild and cultivated pecans as well as native hickory nuts, thousands of acres of pecan orchards have not yet suffered any loss from attack, so far as is known. One grower in Georgia found that out of a crop of 48,000 pounds, so far as he observed, not a single nut was affected by the weevil. Similar reports have been received from large pecan growers in

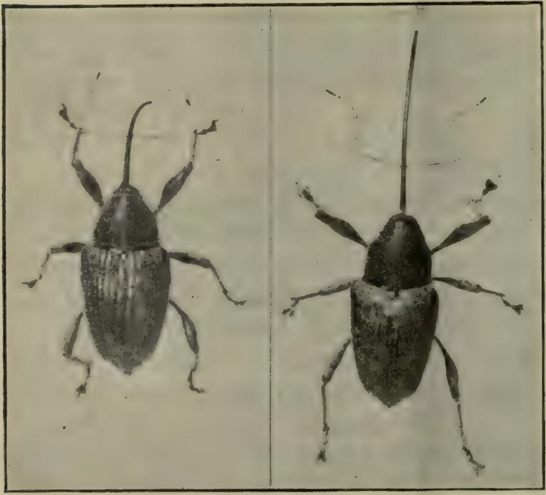

FIG. 13.—The pecan weevil: Adult male at left, adult female at right. Enlarged.

Florida, Mississippi, Louisiana, and Texas. The development of this insect shows four stages: (1) The egg, (2) the larva or grub, (3) the pupa, and (4) the adult or weevil. The parent of the grubs which destroy the interior of the nuts is a small, long-snouted beetle (fig. 13) closely related to the chestnut weevil. The beak, or snout, of the female is much longer than that of the male. The general color of the beetles is dull, dark brown, with a slight tinge of gray.

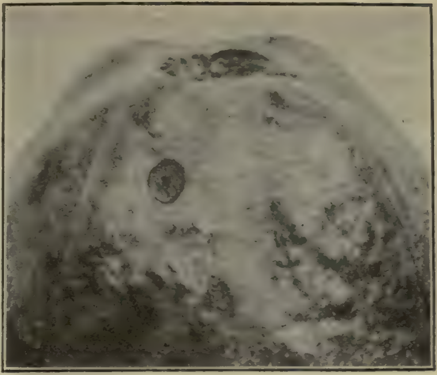

FIG. 14.—The pecan weevil: Egg puncture in the pecan shuck. Enlarged.

The eggs are small, somewhat elongated, irregularly shaped, and translucent white. With her long, slender, but strong beak the female beetle makes a small hole or gallery through the shuck and shell (fig. 14) and with her ovipositor inserts the eggs into the kernel of the nut.

The larva is a robust, yellowish white grub, with a red or light reddish brown head. It is by this stage of the insect that the kernels of the nuts are destroyed (fig. 15). When the larvæ reach maturity they leave the nuts by gnawing circular holes in the shells, and immediately enter the soil to a depth of about 6 to 8 inches and there pass the winter.

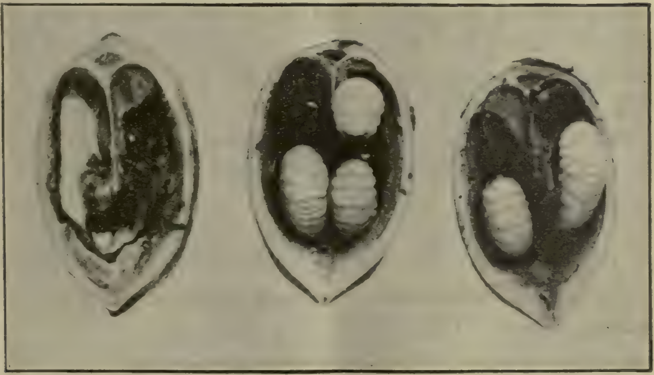

FIG. 15.—The pecan weevil: Grubs, or larvæ, within pecan nuts.

The pupa is of the usual form and is somewhat lighter in color than the larva. It is formed within the soil, in a small earthen cell made by the larva at the time of entering the ground.

SEASONAL HISTORY.

In the South the beetles emerge from the ground and appear on the pecan trees during August and September. Shortly after emergence they are to be found laying eggs in nuts that are approaching maturity. Adults may be found in the ground as late as November, as one specimen, apparently fully developed, was taken on November 23, 1915, about 8 inches below the surface of the soil. The main egg deposition takes place during the first half of September, but apparently eggs are laid over a much longer period, as is evidenced by the time during which larvæ leave the nuts. It has been found that the egg stage lasts about 9 days, and as many as 7 eggs may be deposited in a single nut, although the usual number, perhaps, is 3. According to the writer's records, the larvæ are gnawing their way out of the nuts from September 28 to November 25, although certain observers have reported that the larvæ may leave the nuts as late as January. Immediately upon leaving the nuts they enter the soil to a depth of 6 inches or more for the purpose of hibernation.

CONTROL MEASURES.

The fumigation of chestnuts with disulphid of carbon has been used for a long time as a remedy against the chestnut weevil, and no doubt this treatment will prove effective against the pecan weevil. The nuts to be fumigated should be placed in a tight box or barrel or other receptacle provided with a tight-fitting lid. The disulphid of carbon should be used at the rate of 1 ounce to each bushel of nuts, and fumigation should last for from 24 to 48 hours. The chemical should be placed in a shallow dish or pan on the top of nuts, and immediately after the liquid is poured into the dish the lid should be put in place, care being taken to have it fit tightly. After the nuts have been exposed to the fumes of this gas for from 1 to 2 days, all larvæ will have been killed and the lid should be removed to expose the nuts to the air. Since the vapor of disulphid of carbon is very inflammable when mixed with air, fire should be kept away from it.

The extensive cultivation of the soil in pecan orchards should result in the destructuon of many of the larvæ and pupæ by their exposure to the air and to natural enemies, and where the weevil is prevalent this practice is recommended. After the harvesting of the crop in the fall, hogs should be pastured in the orchard, as they will find the nuts that have been overlooked, and by their rooting into the soil should destroy many of the hibernating larvæ.

INSECTS INJURING THE FOLIAGE AND SHOOTS.

THE PECAN LEAF CASE-BEARER.[1]

The pecan leaf case-bearer is one of the worst pests affecting the culture of pecans, and it occurs in very injurious numbers in orchards in the southern portion of the pecan-growing area, extending from Florida to Texas. Although this insect has been reported definitely from practically all the Southern States in which pecans are grown, it probably ranks as a serious pest only in Florida and the southern parts of Georgia, Alabama, Mississippi, Louisiana, and Texas. The insect occurs also in some of the Northern and Middle Western States where the pecan is not grown, and here it subsists on the various hickories. Generally speaking, the pecan leaf case-bearer is distributed over approximately the same territory as are its preferred hosts, namely, the pecan and hickories. Evidently certain climatic factors limit the destructiveness of this species, and because of these conditions it has not been able, apparently, to become a pest in the northern part of the pecan-growing sections.

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[1] *Acrobasis nebulella* Riley.

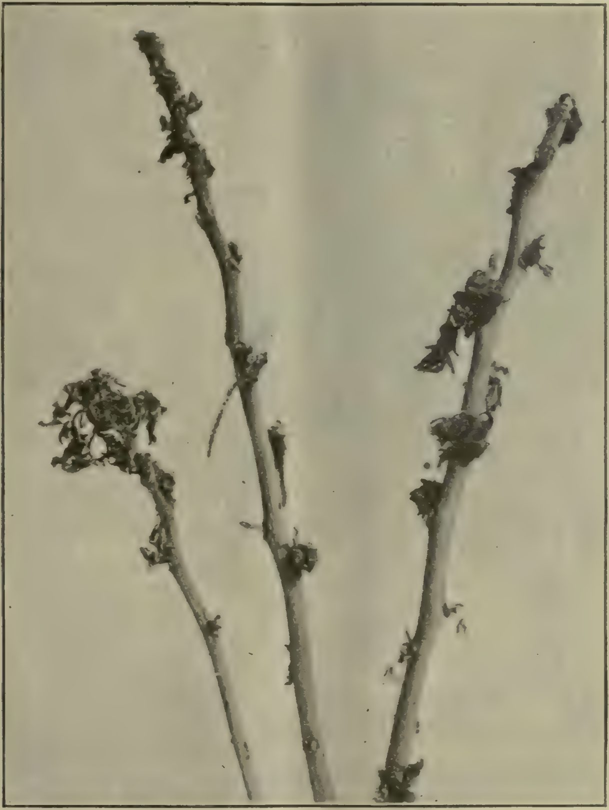

FIG. 16.—The pecan leaf case-bearer (*Acrobasis nebulella*): Injury to young pecan buds in spring by larvæ.

The most serious damage by the leaf case-bearer is done during the early spring and is inflicted by the "worms," which emerge from their winter cases and feed voraciously upon the unfolding buds and leaves. (Fig. 16.) These "worms," or larvæ, are small at this time and dark brown, but soon change to dark greenish as they feed upon the foliage. Upon leaving the winter cases the larvæ enter the buds at the tips and partake of their first meal after having spent several months in hibernation. On badly infested trees the buds and tender leaves suffer serious injury (fig. 17), and often the foliage is consumed by the larvæ as fast as it puts forth. It is not unusual to see pecan trees kept in a defoliated condition for weeks during the spring on account of the attacks of this insect. (See fig. 18.) Since the larvæ are not at all discriminating in their feeding habits, devouring the blossom buds as well as the leaf buds, they are capable of reducing greatly the yield of nuts for the current season, besides leaving the trees in a more or less weakened condition.

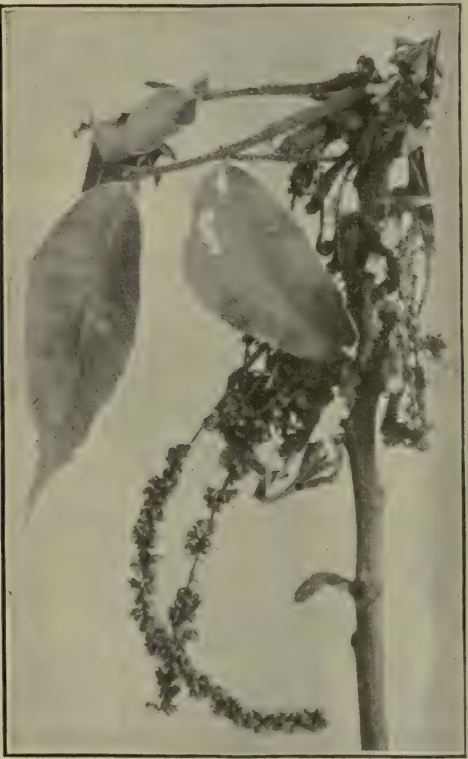

FIG. 17.—The pecan leaf case-bearer: Injury to pecan foliage and flowers.

DESCRIPTION.

As is the case with all moths, the pecan leaf case-bearer has four distinct stages, namely, the egg, the larva, the pupa, and the adult, or moth. The moth (fig. 19) measures about two-thirds of an inch across the expanded wings and presents a wide variation in color. The head, thorax, and base of forewings and legs are snow-white in the males, but in the females these parts are dusky gray. The abdomen is whitish marked with brown. The outer two-thirds of the forewings is gray, with blackish blotches or spots, which are somewhat variable, and not far from the base of the forewings is a reddish brown stain.

The egg (fig. 22) is oval and white, with a slight greenish tinge.

The larva (fig. 20), which is the form that inflicts the injury to buds and foliage, is a dark green, cylindrical caterpillar, measuring a little over a half-inch in length when fully grown. The head is rounded, shiny dark brown or black. The general color of the body is very dark green, except the prothoracic shield, which is somewhat lighter. The skin of the body is very much wrinkled into folds, and the entire body is sparsely covered with fine long hairs.

The pupa (fig. 21), to which the full-grown larva changes, is of the usual form and without conspicuous markings. When first formed it is fairly dark brown, with a tinge of olive green, but with age it turns to a deep shiny mahogany brown. The pupa is formed within the larval case, and upon the emergence of the moth the pupal skin is not extruded, as is the case with some other moths.

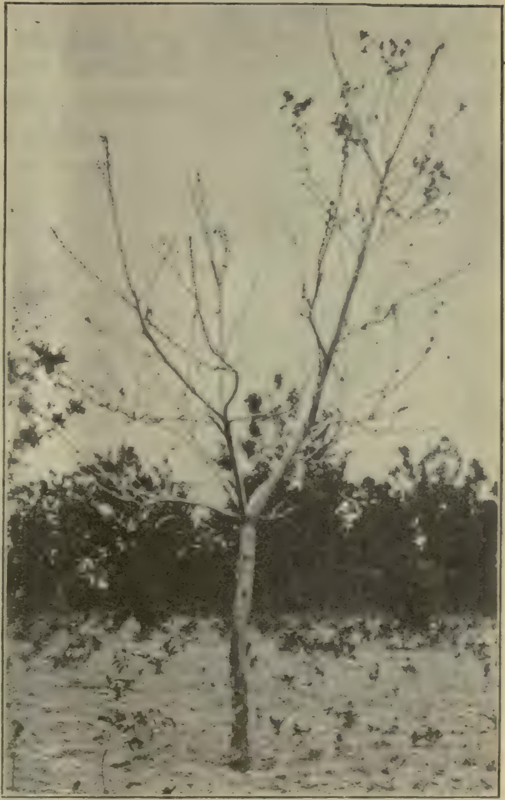

FIG. 18.—The pecan leaf case-bearer: Pecan tree defoliated.

SEASONAL HISTORY AND HABITS.

Only one generation of the pecan leaf case-bearer develops during the course of a year, but more or less variation exists in the development of the different stages, as will be shown presently. For instance, from material under observation during the season 1913 it was determined that the moths, numbering in all 269, emerged between May 9 and July 12, inclusive. During 1914 the dates of issuance for 385 moths varied from May 15 to August 5, and during 1915 the dates at which the 591 moths emerged varied from May 22 to July 23. For the three years the time of greatest, or maximum, emergence was the same, being the latter half of June. Because of the wide variation in moth emergence a corresponding variation occurs also in the time of egg laying. Eggs are deposited always on the underside of the leaves and usually near the junction of the vein with the midrib. (Fig. 22.) The egg stage has been found to last from 6 to 9 days, the average being 7.14 days.

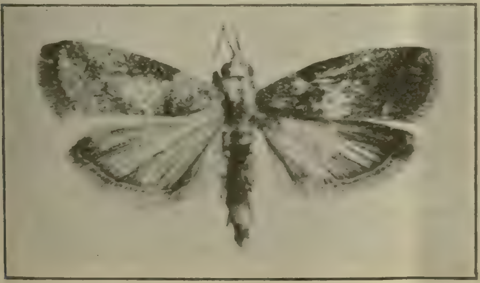

FIG. 19.—The pecan leaf case-bearer: Moth, or parent insect. Enlarged.

The eggs hatch from about the middle of May until the latter part of July or the first few days in August, depending more or less upon the weather conditions. When the young larvæ gnaw their way out of the eggshells they commence feeding upon the portion of the leaflets immediately adjacent to the place where egg laying or oviposition occurred. (Fig. 23.)

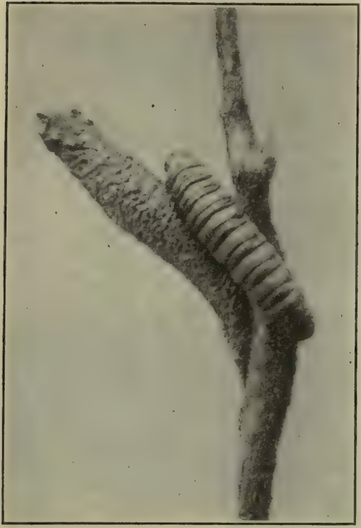
FIG. 20.—The pecan leaf case-bearer: Larva and case. Enlarged.

Throughout the summer and during the early fall the larvæ feed very sparingly upon the foliage, and as they extend their feeding quarters they enlarge their little winding cases (fig. 23), which afford very good protection for them. Although they may feed for nearly three months, or even longer in some instances, they rarely attain a length greater than six one-hundredths of an inch in the fall. During the latter part of September they begin to seek winter quarters around the buds, and here they construct small, compactly woven, oval cases known as hibernacula (fig. 24), and by the middle of October practically all larvæ have left the foliage and are to be found snugly protected in these cases. Shortly before the foliage begins to drop in the autumn the little larvæ abandon the leaves upon which they have been feeding and attach their winter cases securely to the buds and twigs. They remain in hibernation until the latter part of March or the first part of April, at which time the buds on pecan trees usually begin to open.

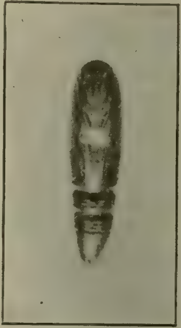
FIG. 21.—The pecan leaf case-bearer: Pupa. Enlarged.

Just as the buds are opening, the larvæ emerge from their winter cases and attack the unfolding leaves. Their pernicious feeding habits at this time result in serious injury to the foliage and in reducing greatly the yield of nuts. The larvæ feed very voraciously during the spring and some of them reach full growth as early as the last days in April, but the majority do not attain full growth until May or early in June. The larvæ always transform to pupæ within their cases (fig. 25), and just before pupation takes place they spin a flimsy layer of silk over the free end of their cases. The pupa period has been found to cover from 16 to 23 days, the average being a trifle over 17 days. The first adults make their appearance about the middle of May and moths continue to come forth until the first week in August. Thus the life cycle of this insect, which it will be seen covers the entire year, is completed.

CONTROL MEASURES.

Although the pecan leaf case-bearer is attacked by a number of parasitic insects, it has been found that the parasites or other natural enemies [1] can not be relied upon to control this pest, but artificial measures of control can be instituted successfully and practically to check its ravages.

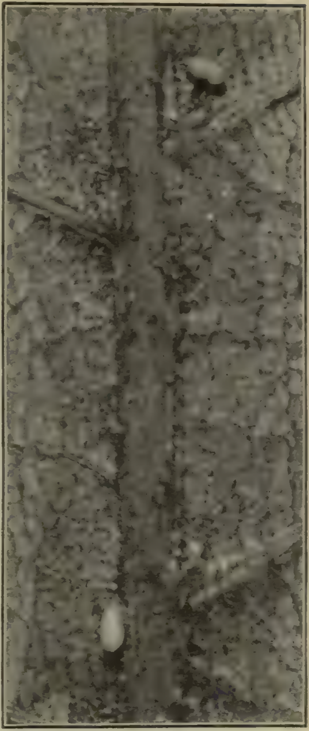

FIG. 22.—The pecan leaf case-bearer: Eggs along midrib on lower surface of pecan leaf. Enlarged.

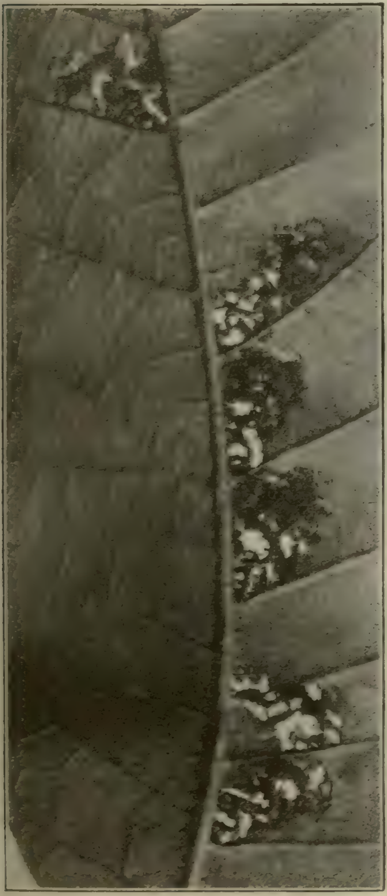

FIG. 23.—The pecan leaf case-bearer: Injury by newly hatched larvæ on lower surface of pecan leaf. Enlarged.

Investigations conducted during the last three years show conclusively that the pecan leaf case-bearer can be controlled by spraying with arsenate of lead during the late summer. The arsenate of lead should be used at the rate of 1 pound of the powdered or 2 pounds of the paste form to each 50 gallons of water, to which should be added 3 pounds of slaked stone lime. Under no circum-

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[1] The following parasites have been reared from this species: *Itoplectis conquisitor* Say, *Triclistus apicalis* Cress., *Calliephialtes grapholithae* (Cress.), *Pristomerus* sp., *Macrocentrus* sp., *Meteorus* sp., *Habrobracon variabilis* Cush., *Orgilus* sp., *Secodella acrobasis* Cwfd., *Spilochalcis vittata* (Fab.), *Cerambycobius* sp., *Trichogramma minutum* Riley, *Exorista* sp., and *Leskiomima tenera* Wied. Three species of birds, namely, the blue jay, the mockingbird, and the orchard oriole, have been observed feeding upon the larvæ.

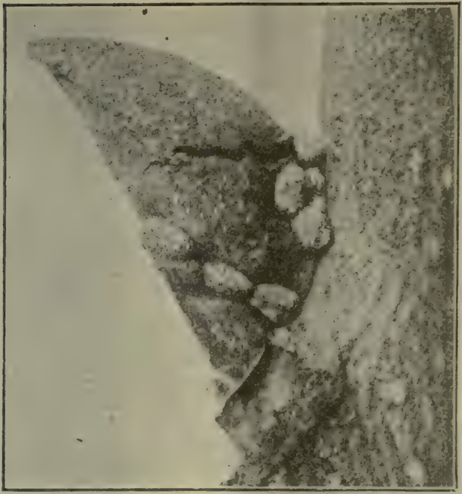

FIG. 24.—The pecan leaf case-bearer: Winter cases, or hibernacula, around pecan bud. Enlarged.

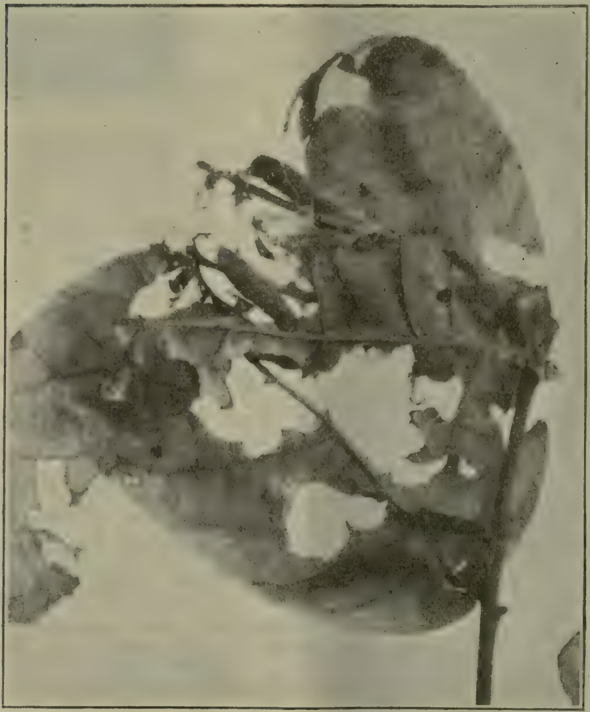

FIG. 25.—The pecan leaf case-bearer: Larvæ in their cases and injury to pecan leaflets.

stances should the arsenate of lead be used without the addition of lime, as more or less serious injury to the foliage or nuts is likely to result. Spraying may be done with the same degree of effectiveness from the first part of August up to the middle of September. Care should be taken not to delay the spraying too long in the fall, as observations have shown that some larvæ seek hibernation quarters toward the latter part of September, although the vast majority of them do not construct winter cases until the first week in October. It should be borne in mind also that only the larvæ that have fed on poisoned foliage will be killed. Remembering these points, growers should realize the importance of spraying at the proper time and apply the poison thoroughly to all parts of the foliage, especially the under side, upon which the larvæ are feeding. Only one thorough application is necessary to control this pest in pecan orchards, even though the infestation is most severe. It is unnecessary to spray more than once for this pest providing the spray is applied thoroughly at the proper time.

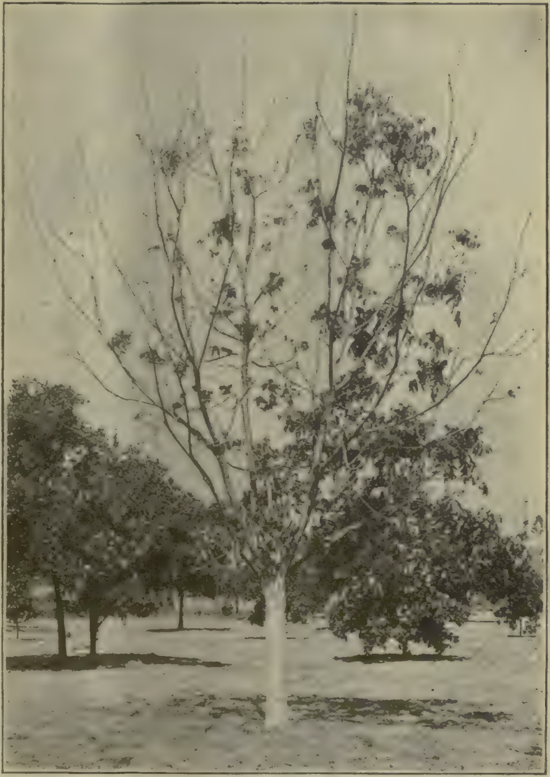

FIG. 26.—The pecan cigar case-bearer (*Coleophora caryaefoliella*): Pecan tree largely defoliated by this insect.

THE PECAN CIGAR CASE-BEARER.[1]

The pecan cigar case-bearer usually is to be considered as a pest of only minor importance, but reports are received of its occurrence in injurious numbers in pecan orchards during the spring months and of the infliction of serious damage to the buds and foliage. (Fig. 26.) This insect does not confine its attacks to the pecan, as it feeds upon the various species of hickory and the black walnut. The pecan cigar case-bearer is distributed over a wide range of the country,

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[1] *Coleophora caryaefoliella* Clem.

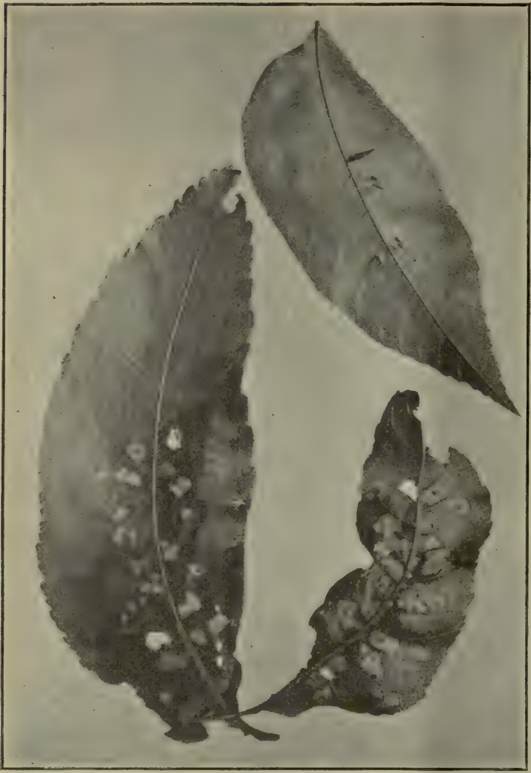

FIG. 27.—The pecan cigar case-bearer: Type of injury by larva to pecan leaflets.

extending from Florida to the extreme western border of Texas, and as far north as New Hampshire. When the buds of pecan trees are opening, or just after they have begun to unfold, the hibernating larvæ become active and attack them, continuing their feeding operations on the foliage (fig. 27) until about the middle of May (in Florida), when they become full grown and transform to pupæ within the larval cases (fig. 28, *b*, *c*). The pupa period lasts about two weeks, and during June the moths (fig. 28, *a*) appear in numbers on the pecan. The eggs are deposited on the foliage and they hatch within a few days. Upon hatching, the larvæ feed first as leaf-miners, but later in the season they construct the small cases, in which they feed upon the leaves until a short time before the foliage drops in the fall. The larvæ migrate then to the twigs or larger limbs or trunks, where they attach their cases and spend the winter.

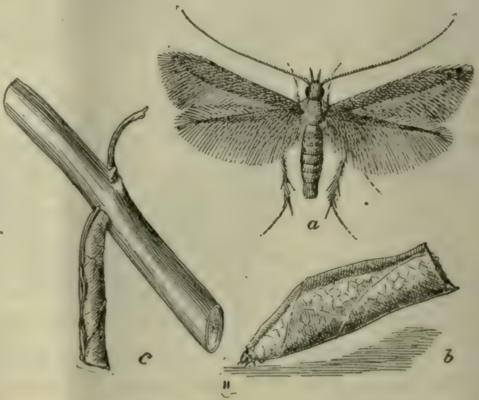

FIG. 28.—The pecan cigar case-bearer: *a*, Moth; *b*, *c*, larvæ in cases. Enlarged. (Russell.)

CONTROL MEASURES.

If this insect occurs in injurious numbers in the spring it can be controlled readily by spraying the trees with arsenate of lead at the rate of 1 pound of the powdered or 2 pounds of the paste form to each 50 gallons of water, to which should be added 3 pounds of slaked stone lime. This species, however, rarely is abundant enough in orchards to call for special treatment. In pecan orchards in which spraying is directed against the more injurious pests the pecan cigar case-bearer rarely will be a source of trouble, as the larvæ of this and the other species are killed by the same treatments.

THE PECAN BUD-MOTH.[1]

The pecan bud-moth is a pest of greater or less importance in the pecan orchard and nursery. At times it becomes so abundant that the damage caused by the larvæ feeding upon the terminal buds of pecan nursery stock entails considerable loss to nurserymen. This insect evidently occurs throughout the pecan-growing region, as reports of damage have been received from most of the Southern States. Besides feeding upon the pecan, it has been recorded doubtfully from various hickories, and doubtful records exist of its occurence on the black walnut.

DESCRIPTION.

The general color of the moths is gray, mottled with blackish-brown patches and streaks, and the expanse of wings is just a little more than half an inch. The blackish-brown patches on the forewings are arranged in a zigzag fashion from the base of each wing across its middle to the tip. The hindwings are without markings and are dusky gray, with the outer margin somewhat darker. The moths are very active and are often found frequenting the tree trunks, on which they rest head downward. When disturbed the moth will fly away in a jerky manner for a short distance and then suddenly wheel about to return to the tree trunk that it just left.

The eggs (fig. 30) are small, oval, whitish, and iridescent in some lights. When the trees are in foliage the eggs are laid upon the upper surface of the leaves, but before the buds push forth in the spring eggs are often found deposited on the twigs.

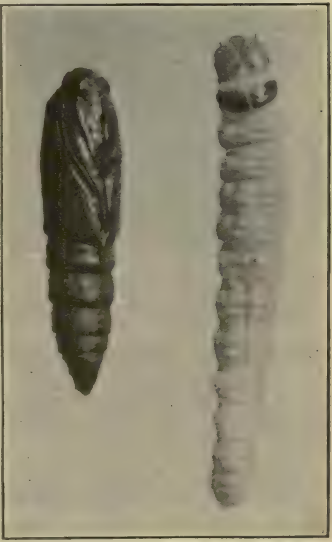

FIG. 29.—The pecan bud-moth (*Proteopteryx bolliana*): Pupa at left, larva at right. Enlarged.

When full grown the larva (fig. 29, at right) is about five-eighths of an inch in length. The body, which is sparsely covered with fine hairs, is yellowish green, and through its semitransparent skin can be seen the brownish contents of the alimentary canal. The head and cervical shield, or neck, are shiny dark brown in color in full-grown larvæ, but on very young larvæ they are jet black.

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[1] *Proteopteryx bolliana* Sling.

The pupa (fig. 29, at left) is of the usual light-brown color. The size varies somewhat, but the length rarely is more than a third of an inch. The pupæ usually are formed in rolled-up leaves or infested buds, but occasionally they can be found under bark scales or at the crown of the tree.

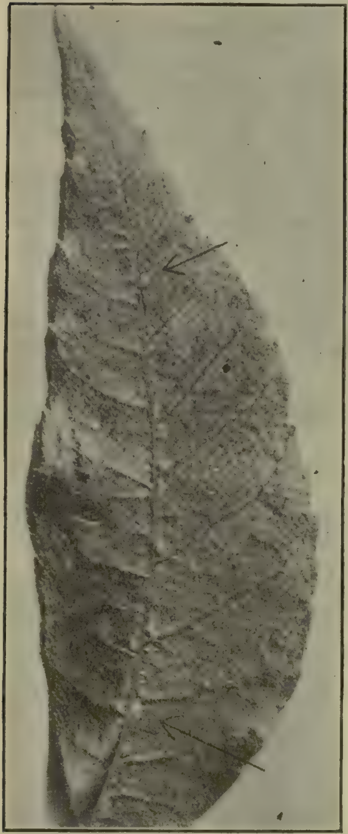

FIG. 30.—The pecan bud-moth: Eggs on pecan leaflet.

SEASONAL HISTORY.

The number of generations a year varies somewhat in different sections. In the extreme southern portion of its distribution five or six occur during the course of a season. The pecan bud-mouth passes the winter in the adult stage. As soon as the buds on the pecan trees begin to open, the moths commence to lay eggs, which usually are deposited on the branches near the buds, but after the foliage appears the eggs are laid invariably on the upper surface of the leaves. (Fig. 30.) The eggs hatch in from 3 to 6 days, depending upon the temperature. The larvæ feed from 21 to 29 days, the average being about 25 days. The pupa stage lasts from 8 to 13 days, but the average period is about 10 days. The average life-cycle period is 40 days—5 days being spent in the egg stage, 25 days as larva, and 10 days as pupa.

CONTROL MEASURES.

Ordinarily this bud-moth does not occur in sufficient numbers to be ranked as a serious pest of the pecan. In bearing pecan orchards it is rarely troublesome, but during some seasons it is responsible for considerable damage to the pecan nursery trees. This species is primarily a bud feeder, and in attacking the terminal buds on the young trees it causes a stunted growth as well as excessive branching. This feature is especially objectionable from the nurseryman's point of view, since the pecan nursery stock is sold according to its height. It has been observed that nursery trees growing vigorously usually open and unfold their terminal buds so rapidly that the larvæ apparently do not have sufficient time to inflict serious damage. It has been observed, further, that the larvæ feed on the foliage (fig. 31) if compelled to do so by the rapid growth of the tree, and under these conditions they will eat the outer parts of the leaves. During dry seasons, especially in the spring of the year, pecan nursery stock grows very slowly and is seriously injured by larvæ of the bud moth. As a nursery practice it is strongly recommended that the trees be kept in a vigorous growing condition by thorough cultivation and fertilization. Spraying with arsenicals during the spring just as the buds are opening will help materially to hold this pest in check, but this treatment is not advised unless the infestation is very serious. Observations would indicate that the pecan bud-moth never does sufficient damage in bearing orchards to warrant special spraying.

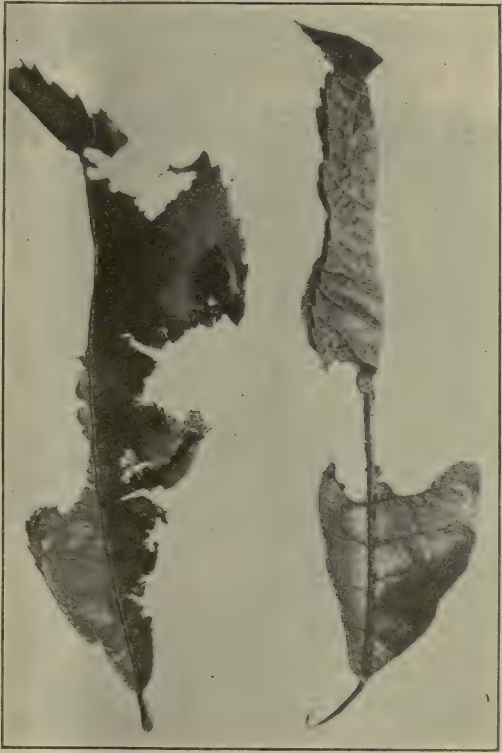

FIG. 31.—The pecan bud-moth: Larval injury to pecan foliage.

THE FALL WEBWORM.[1]

Perhaps the commonest insect coming under the observation of pecan growers is the so-called fall webworm, which constructs unsightly nests or webs over the twigs and foliage. These webs are more abundant during the late summer and fall, but since this insect has two generations in the South, the webs are to be found on pecan trees as early as May. Trees defoliated in late summer frequently develop leaves and flowers to the detriment of the crop the following year.

The moths (fig. 32), which usually are pure white but sometimes have black or brown spots on the forewings, emerge in the spring, during April and May. The eggs are deposited in masses on the leaves, are greenish white in color, and hatch in about a week (fig. 32). The larvæ are gregarious, and each colony forms a web in which all the caterpillars feed, eating the upper and lower surfaces of the leaves. When they need additional leaves for food they enlarge the web (fig. 33), which sometimes becomes very large and conspicuous.

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[1] *Hyphantria cunea* Drury.

The full-grown larvæ (fig. 34) usually measure an inch in length and are covered with long white and black hairs arising from numerous tubercles. On reaching maturity they leave their webs and transform to brown pupæ in flimsy, hairy cocoons beneath rubbish on the ground, under the scales of bark, or just under the surface of loose soil. The earliest date for the emergence of moths of the second brood is June 26, but most of the moths of this generation do not appear until later. The second-brood larvæ have been found deserting their webs during the latter part of September, all through October, and occasionally as late as the first week in November, for the purpose of pupation. This insect passes the winter as pupæ, and moths appear the following year, during April and May.

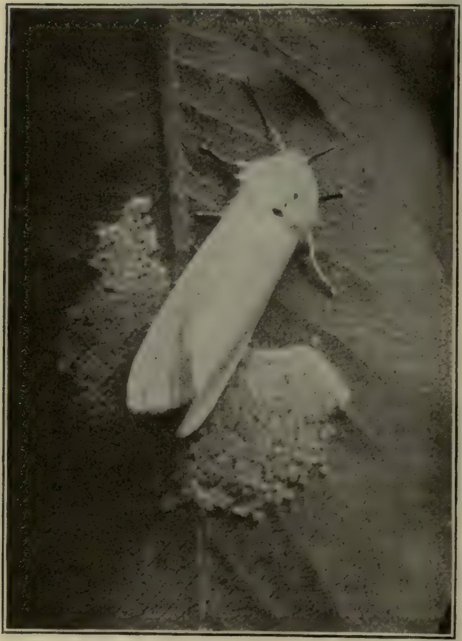

FIG. 32.—The fall webworm (*Hyphantria cunea*): Moth and egg mass. Enlarged.

CONTROL MEASURES.

All webs containing caterpillars that can be reached conveniently should be removed and the larvæ destroyed. Sometimes burning the webs on the trees will be found practicable, but it should be done carefully, so that much of the foliage will not be scorched. A long-handled tree pruner can often be used to advantage in removing the webs that are well up in the trees. When the fall webworm is extremely abundant, as is the case in some years, the foregoing measures can be effective to a limited degree only. Pecan orchards sprayed for the pecan leaf case-bearer will suffer no material damage from this insect, as the same treatment will destroy these caterpillars as well as several other leaf feeders.

THE WALNUT CATERPILLAR.[1]

In the South branches of large pecan trees often are defoliated by colonies of a caterpillar which when full grown is black, with long whitish hairs, and nearly 2 inches in length. This is the so-called walnut, or pecan, caterpillar. When young it is brownish, with white stripes and somewhat more hairy than the matured

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[1] *Datana integerrima* G. & R.

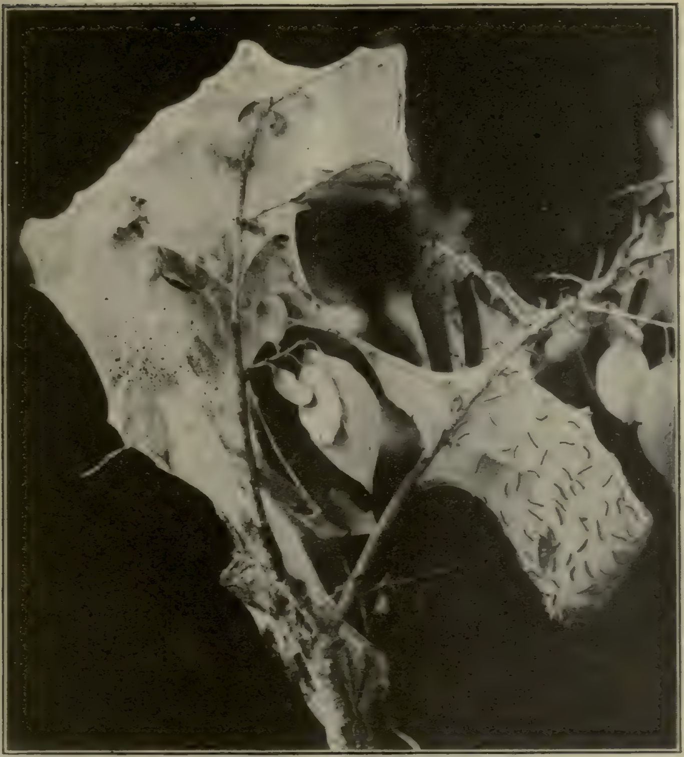

FIG. 33.—The fall webworm: Web and caterpillars.

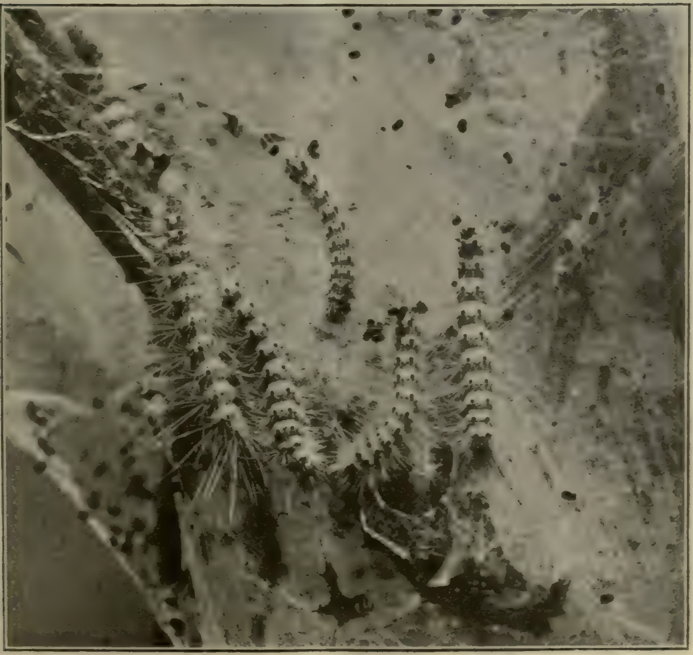

FIG. 34.—The fall webworm: Portion of web enlarged, showing larvæ.

larva. The larvæ upon hatching from eggs, which are deposited in masses (fig. 35) on the underside of the leaves, feed at first only on the underside of the leaflets, but later they devour the entire foliage except the stems and petioles. Small pecan trees, especially nursery stock, sometimes are defoliated completely, and it is not uncommon to see large branches on bearing trees stripped of their foliage. The larvæ feed in colonies (fig. 36), and in molting the larger caterpillars invariably leave their feeding place and crawl to the trunk or larger limbs, where in a mass they shed their skins, which may adhere to the bark for several weeks or longer. After molting they ascend the tree to continue their feeding depredations, and when fully grown crawl down the trunk and immediately enter the soil to a depth of a few inches. Here, in a day or two, pupation takes place.

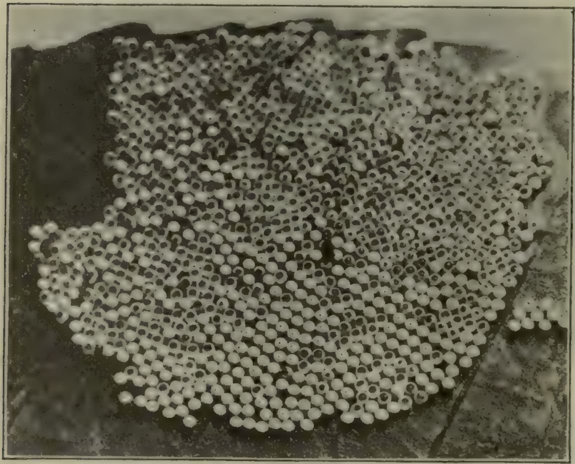

FIG. 35.—The walnut caterpillar (*Datana integerrima*): Egg mass. Enlarged.

In the North this insect has only one generation yearly, but evidently at least two generations occur in the South.

According to Bureau of Entomology records the moths (see fig. 37) developing from overwintering pupæ emerge from April 15 to July 15, and shortly after emergence egg laying takes place on the underside of the leaflets. The eggs, which are laid in masses usually numbering from about 100 to 150 each, hatch in a little less than a week and the larvæ feed for 25 days or longer before completing their growth. The caterpillars enter the soil to transform to brown pupæ, in which state they remain about 18 days for the summer generation. In the case of the fall generation the winter is passed as pupæ (fig. 38) in the ground and the moths do not emerge until the following spring or early summer. The second-brood larvæ enter the soil from the middle of September until the last week in October.

CONTROL MEASURES.

Whenever the egg masses or colonies of the caterpillars are discovered they should be destroyed promptly. Growers often may discover the larger larvæ massed on the tree trunks in the act of molting, and these should be destroyed by crushing or some other suitable means. Pecan orchards sprayed with arsenicals will rarely suffer serious damage by this insect.

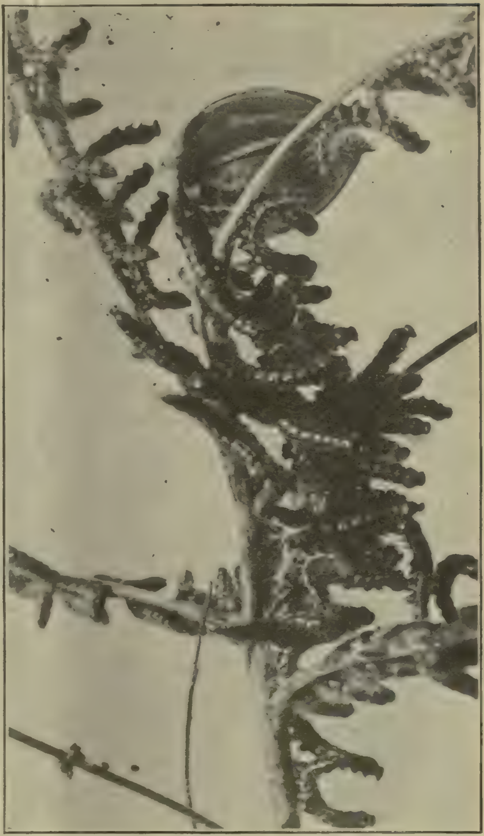

FIG. 36.—The walnut caterpillar: Colony of larvæ on pecan.

THE HICKORY PHYLLOXERA.[1]

Pecan growers are alarmed occasionally by the presence of tumor-like swellings or galls (fig. 39) which sometimes occur on the leaves, leafstalks, and succulent shoots. These galls are caused by the attacks of an insect and are in no way to be associated with a disease organism, as seems to be a more or less prevalent notion among pecan growers. An examination of one of the newly matured galls will reveal the true culprit in both winged and wingless or immature forms. Before the maturity of the inhabitants the gall is closed, but by the time the inmates have acquired wings it cracks open, allowing the fully developed migrants or aphids to escape, and is left for the younger individuals.

The formation of galls is more pronounced during the early spring than at any other time, although galls may be found on the trees during the greater part of the growing season. Both the seedling and improved varieties of pecan are subjected to the attacks of these aphids, but it appears that injury is much more prevalent to the seedlings. It is not uncommon

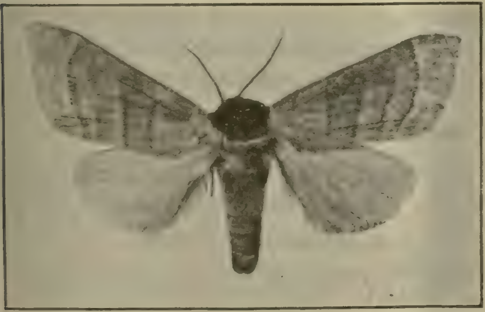

FIG. 37.—The walnut caterpillar: Adult, or moth. Slightly enlarged.

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[1] *Phylloxera caryaecaulis* Fitch, and other species.

to find seedling nursery stock covered with galls, but budded or grafted pecan trees growing adjacent may, and usually do, escape injury.

Certain pecan trees in orchards are exceptionally subject to attacks by this insect, while trees growing immediately adjacent to the affected ones are not attacked and mature their full crop of nuts. Judging from the past behavior of the hickory phylloxera, it does not appear that this insect will be a very serious drawback to commercial production of improved varieties of the pecan under orchard conditions. This aphid attacks certain species of hickory as well as the pecan.

CONTROL MEASURES.

Under ordinary circumstances pecan trees slightly infested by this insect will hardly demand special remedial measures. Like many other insects, this species is subject to great fluctuation in numbers, and the amount of damage therefore will vary considerably from year to year. This variation in abundance is due to the fact that the insect is held more or less completely in check by natural enemies.

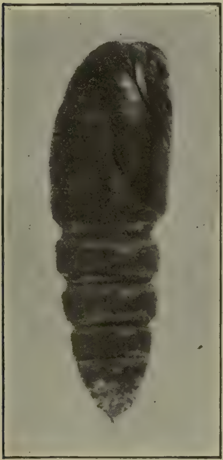
FIG. 38.—The walnut caterpillar: Pupa. Somewhat enlarged.

So far as present knowledge of this insect goes, no very satisfactory method of control can be employed during the growing season on trees that are so badly affected that the nut crop is seriously interfered with. It has been recommended that as many as possible of the badly affected leaves and shoots be clipped off by means of a 12-foot pruner before the galls open, and then burned immediately; but this treatment will hardly prove feasible for large trees. Perhaps the insect could be destroyed while in the egg stage, during the dormant season, by spraying with lime-sulphur solution, kerosene emulsion, or miscible oil; but so far no actual work along this line has been undertaken.

If certain varieties of pecans show an exceptional susceptibility to infestation year after year, top-working such trees with resistant sorts doubtless would prove a practicable means of avoiding injury by this species.

THE LITTLE HICKORY APHID.[1]

Often during the course of the season, especially in the spring and autumn, pecan foliage is seen to be infested by a little lemon-yellow aphid or plant-louse. This insect is commonly called the little hickory aphid, because it was first discovered feeding upon the hickory and because of its small size. Besides feeding upon the hickory and pecan, it has been reported infesting the California black walnut [1] and hybrids derived from this tree.

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[1] *Monellia caryella* Fitch.

About the time the buds on pecan are opening, the eggs of this aphid begin to hatch. Later the mature insects migrate to the unfolding foliage, upon which they feed by sucking the juice from the plant. They continue their feeding operations throughout the growing season, or until the trees shed their leaves. Throughout the spring and summer the non-sexual forms give birth to living young, but in the autumn (September and October) the sexual forms make their appearance on the trees and after mating the females deposit eggs on the twigs. These do not hatch until the following spring.

Fortunately this insect does so little damage to pecan foliage that no special remedial measures are required. Its many natural enemies help much in keeping it in check. A significant feature about the infestation by this aphis is the abundance of "honeydew" excreted upon the foliage. Usually leaves covered by the sticky excretions support the growth of a black fungus which makes the foliage look unsightly and perhaps interferes to some extent with the proper respiratory action of the plant.

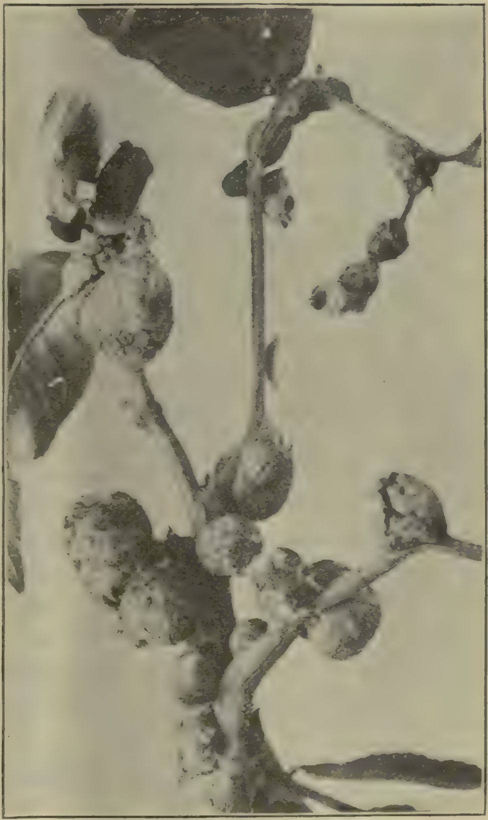

FIG. 39.—The hickory phylloxera (*Phylloxera* sp.): Galls on pecan.

INSECTS INJURING THE TRUNK AND BRANCHES.

"WHITE ANTS," OR TERMITES.[2]

Pecan trees, as well as other kinds of plants, occasionally are injured and sometimes killed by attacks of the so-called white ants, or termites. Pecan growers in certain sections are familiar with these pests under the name "wood lice," the insects being so named because they often mine large galleries in dead wood and foundation timbers. On account of their underground habits and method of attack, termites usually escape detection until serious damage has been done, and are destroyed with great difficulty. The reports of injury to pecan trees have been confined for the most part to seedlings 1 or 2 years old growing on recently cleared land. Sometimes young budded and grafted pecan trees are injured or killed by termite attacks, but in most if not all cases the orchards were set out on new land containing an abundance of dead wood and humus.

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[1] *Juglans californica.*

[2] *Leucotermes flavipes* Kollar is the most widespread and abundant species of termite in the Eastern States.

As is the case with true ants, termites live in colonies, and because of their similarity to ants in appearance and habits the name "white ants" has come into more or less common usage. Termites only occasionally attack living trees, their principal and most serious damage being done to foundation timbers and woodwork of buildings. In cut-over woodlands they often are prevalent under the bark of dead logs or beneath the fragments of wood lying on the ground. On small seedling trees from 1 to 2 years old the taproot frequently is hollowed until little more than a shell of bark remains. (Fig. 40.) Termites usually gain entrance to the trees below ground, but their galleries may extend for an inch or so above the soil inside the heartwood. Apparently they attack grafted trees at the point where the graft has not healed over smoothly with the seedling stock.

The affected trees as a rule do not show any indication of injury until they are damaged beyond remedy, and then they die very quickly, as is shown by the sudden wilting of the leaves.

CONTROL MEASURES.

Because of the underground habits of termites it is difficult to apply a direct remedy to affected trees. Since they live in colonies and their nests usually are in the ground somewhere near the affected trees, it is important not only to kill the termites within the trees, but also to locate and destroy the inhabitants of the nests, in order that permanent results may be obtained. Nests perhaps can be destroyed best by pouring carbon disulphid into them and then immediately packing the soil around the nest. This is a volatile liquid, and the gas, being heavier than air, will penetrate all recesses of the nest and cause the destruction of the termites. Since carbon-disulphid treatment is somewhat dangerous to plant life, care should be employed not to use very large dosages around the trees. Sprinkling of tobacco dust in the nests and around the roots of affected trees has been reported to give good results, but the writer never has seen this treatment in practice, and therefore can not recommend its use with any degree of certainty as to its effectiveness.

The injury to pecan nursery stock will be most serious on recently cleared land where decaying wood is abundant, as termites show a decided preference for such wood as a breeding place. New land to be planted to nurseries should have all dead wood removed from the soil, and the growing of two or three farm crops on the land is advisable before planting the seedling nuts for the ultimate propagation of budded and grafted trees. As a nursery practice, for the prevention of attack by this insect, it is urged strongly that recently cleared land be avoided. The same advice holds true in case a young pecan orchard is to be set out, as prevention is a far more reliable method of fighting the pest than is the use of any direct remedy.

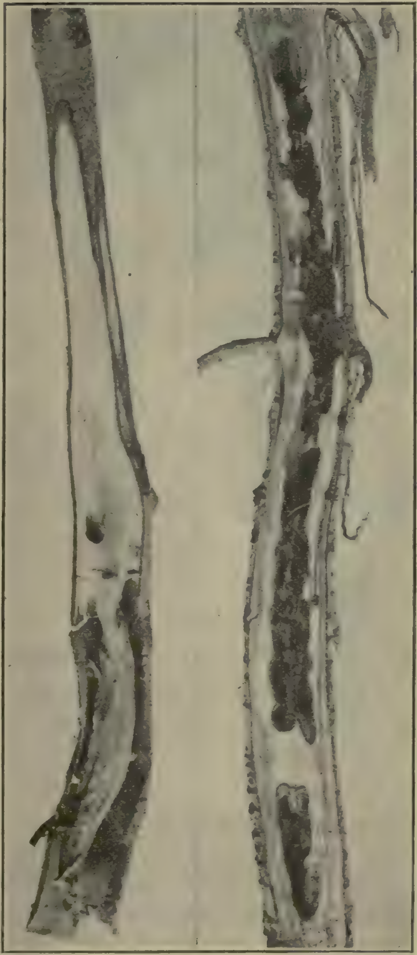

FIG. 40.—The white ant (*Leucotermes flavipes*): Injury to roots of pecan nursery stock.

THE OAK OR HICKORY COSSID.[1]

The oak or hickory cossid in its larval state inhabits the trunks or larger branches of pecan, hickory, and oaks, in which it bores or tunnels in the hard wood, making galleries several inches in length. The work of the larva is detected rather readily by the castings of wood that are distributed at the base of the tree trunks. A careful search of the affected trees will reveal the hole from which these castings are pushed out by the larva, in order that its larval gallery may be kept clear. When the larva is full grown, it considerably enlarges this hole, which is more or less oval in shape, and then transforms to pupa. Just before the adult insect is ready to emerge, the pupa wriggles its way to the mouth of its gallery, and upon the issuance of the moth the pupal case is left protruding a little from the exit hole.

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[1] *Cossula magnifica* Strecker.

DESCRIPTION.

The moth (fig. 41) generally is gray, mottled with brown and black blotches, and has an expanse of wings of about one and three-fourths inches. Each forewing has a large, light brown patch, sprinkled at the end with dark-brown streaks. The hind wings are darker gray than the forewings and are without any markings. The head is brown, the thorax light gray, peppered with faint dark spots, and the abdomen brownish gray.

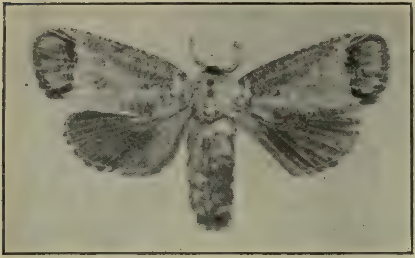

FIG. 41.—The oak or hickory cossid (*Cossula magnifica*). Adult, or moth. Very slightly enlarged.

The full-grown larva (fig. 42) is about 1½ inches in length. The body is pinkish in general color and covered sparsely with short fine hairs which arise from the numerous tubercles. The head, cervical shield, or neck, and plates on the hind end of the body are shiny dark brown.

The pupa, to which the larva transforms upon attaining full growth, is generally brown, except the anterior part, which is blackish. On its head is a sharp projection which is of assistance to the pupa in pushing its way out of the larval burrow preparatory to the emergence of the adult moth.

SEASONAL HISTORY AND HABITS.

The complete life cycle of this insect is not known, but it probably occupies only one year in the extreme South, and longer in its northern distribution. The moths emerge usually during May and June, and lay their eggs shortly after their appearance. The larvæ upon hatching first attack small twigs, in which they tunnel out the center or pithy wood. (Fig. 43.) When the larva has grown too large for the small twig upon which it has been feeding, it crawls out and enters a larger limb. By the early fall the larvæ will be found attacking the tree trunks or very large lower branches, in which they bore into the hard wood and make their galleries parallel with the grain. At this time and during the spring months the grower can detect piles of pellets of frass or castings at the base of the trees, and this is a very good way to locate the insect in pecan orchards. The transformation to pupa takes place within the larval gallery during April or May. By means of the sharp toothlike protuberance on

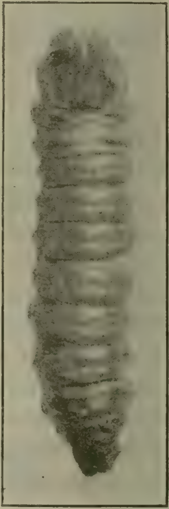

FIG. 42.—The oak or hickory cossid: Larva. Enlarged.

the head end the pupa wriggles along the tunnel to the exit hole, after which the skin splits open and the moth emerges.

CONTROL MEASURES.

All that can be done to control this insect in pecan orchards is to locate the larger limbs and tree trunks attacked, and destroy the larvæ by injecting small quantities of carbon disulphid into the holes, which should be stopped up immediately after treatment by means of putty, grafting wax, wooden pegs, or moist clay.

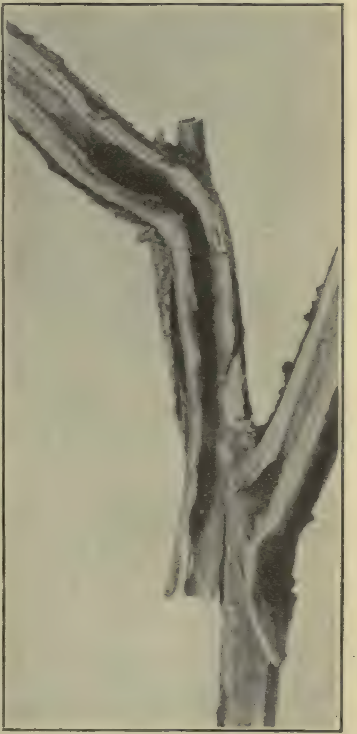

FIG. 43.—The oak or hickory cossid: Larval burrow in pecan twig. Enlarged.

THE FLAT-HEADED APPLE-TREE BORER.[1]

The flat-headed apple-tree borer has been known long as a more or less serious pest of certain fruit trees, such as the apple, quince, pear, peach, and apricot, and among its food plants are to be included several shade and forest trees. During the last few years this insect has been recognized in many sections of the pecan-growing belt as a serious enemy of pecan trees grown under orchard conditions, and in innumerable cases its larvæ have girdled and killed young trees. Its injuries are for the most part restricted to newly transplanted nursery trees and to trees that suffer from uncongenial soil or droughts, or are damaged by "barking" with cultivating implements. Pecan trees that have been affected by winter injury are very susceptible to the attacks of this borer. It is well known that pecan nursery stock does not stand transplanting so well as do many orchard fruit trees, as, for instance, the apple or peach, and perhaps this is because so much of the taproot is cut off in removing the trees from the nursery row. For the first year or two transplanted pecan nursery trees make little growth and do little more than establish themselves, even when the planting is done at what is considered the best time and with the utmost care. If the spring and summer following the setting out of the young trees are deficient in rainfall, the trees may be more or less seriously attacked by flat-headed borers, as the beetles seem to prefer to lay their eggs upon weakened or devitalized trees.

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[1] *Chrysobothris femorata* Fab.

DESCRIPTION.

The beetle, as represented in figure 44, is oval and flattened and about one-half inch in length, but the size is somewhat variable. The antennæ, or "feelers," are short and toothlike, the eyes rather large, and each leg of the first pair is armed in front with a conspicuous tooth. The upper surface has a brownish metallic luster, the color of the underside is coppery bronze, and the part of the body underneath the wing covers is bright metallic greenish blue. The markings on the back, or wing covers, are well shown in the illustration.

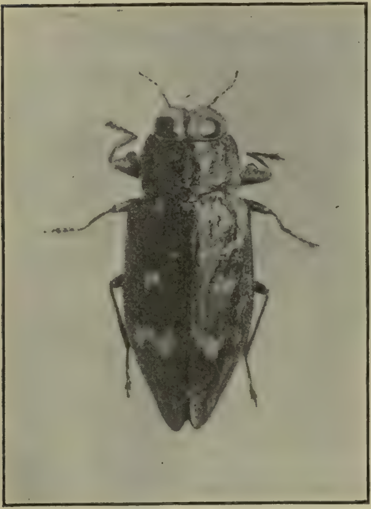

Fig. 44.—The flat-headed apple-tree borer (*Chrysobothris femorata*): Parent beetle. Enlarged.

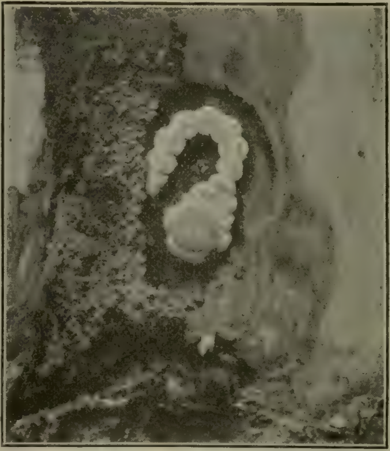

Fig. 45.—The flat-headed apple-tree borer: Larva in its burrow. Enlarged.

The larva (fig. 45) when full grown is about an inch long, without legs, and yellowish white. The second thoracic segment is much broadened and compressed, giving the larva the appearance of having a large flattened head. The larvæ within their galleries always assume a curved position, somewhat as is shown in the figure.

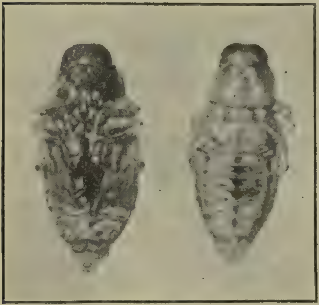

Fig. 46.—The flat-headed apple-tree borer: Pupa, ventral and dorsal views. Enlarged.

The pupa (fig. 46) is also yellowish white, somewhat more yellow than the larva, and it shows the undeveloped appendages and structures of the adult beetle.

SEASONAL HISTORY AND HABITS.

The beetles are to be found in pecan orchards from March to November, but they are especially abundant at two periods, namely, during May and from the middle of August until mid-

September. The beetles deposit their eggs in cracks or under bark scales upon the trunk or larger limbs. The young larva upon hatching gnaws through the bark and begins to feed upon the sapwood immediately beneath, making a more or less irregular gallery packed with sawdust castings, the gallery usually being evident through the bark. Some galleries have a very tortuous or spiral course (fig. 47), and because of this the affected trees are often girdled. If the trees are able to maintain considerable vitality in spite of the attacks, the larvæ do not enter the sapwood to transform to pupæ, as they do in dead and dying trees, but transformation to pupa takes place immediately under the bark, a slight excavation being made in the sapwood. One year is required for the complete development from egg to adult. Because of the different sizes of larvæ that may be found in trees at almost any season of the year, many growers believe that the insect has more than one brood. This, however, is to be explained by the great variation in rate of growth of the larvæ and the consequent variation in time of emergence of the beetles, this emergence taking place any time from March until early autumn.

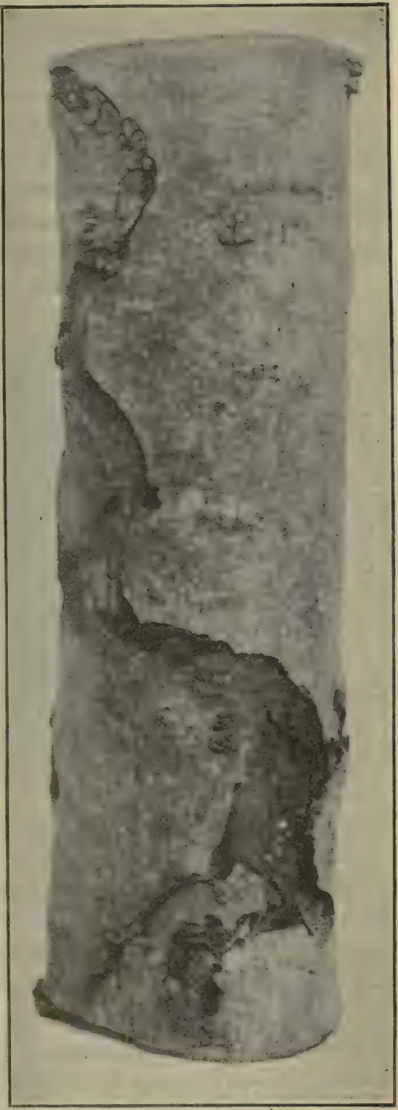

FIG. 47.—The flat-headed apple-tree borer: Larval burrow in trunk of young pecan tree.

CONTROL MEASURES.

After borers have gained entrance to the trees nothing better can be done than to examine the trees carefully and remove the larvæ with a knife. The point of infestation on the trunk or limb usually can be detected by the discoloration and depression of the bark, which sometimes cracks open. In badly infested orchards the trees should be examined at least twice a year, and perhaps a third time would be advantageous. In cutting out "worms" great care should be taken not to cause any unnecessary injury to the trees, and the places from which the borers have been removed should be painted with white lead or some good tree paint.

Certain washes have been used with some little success for protection against this insect in apple orchards, but it is believed that this means of fighting the borer on pecan is impracticable. Since the beetles are to be found in pecan orchards from March until November, several applications of the wash would be required and the cost for the treatment would be excessive.

In pecan orchards the use of trap logs made from newly cut branches of any favorite host plant, in order to attract the adult beetles for egg deposition, may be found practicable, for it is well known that this insect prefers dead or dying wood to living trees. Perhaps oak would be the best and most available wood to be had for these logs, but hickory or pecan would serve the same purpose, as the borer breeds abundantly in all of them. These trap logs, from 4 to 6 feet in length and from 3 to 4 inches in diameter, should be placed at intervals of 100 feet or less during the late winter or very early spring. After these logs have been left in the orchard for one season they should be burned the following winter. The writer has captured hundreds of beetles on pecan and oak logs that were smeared with a viscous substance and placed in pecan orchards. This plan has not been tested on a large scale, but it promises to be of value, especially in badly infested orchards that have been neglected for some time and are adjacent to extensive woodlands.

Careful cultural methods are urged strongly as a measure of protection. All dead and dying trees and all pruned limbs or branches should be removed promptly and burned, for such wood affords an ideal breeding place for the borer and is therefore a menace to the orchard. The keeping of pecan wood about the orchard for future use as fuel or for other purposes is a bad orchard practice and can not be condemned too strongly. In several instances the writer has found large numbers of flat-headed borers in limbs and branches of pecan stored for firewood. In the transplanting of nursery stock to the orchard, every care should be taken to have the trees set out under the best conditions; and, judging from observations, early planting, say, in December and January, and not later than February, is to be recommended, so that the trees will get the benefit of the winter rains. As a measure of protection it is also essential that young trees be kept in a vigorous growing condition by frequent cultivation and the planting of tree rows to some suitable leguminous crop. The use of fertilizers also will help the trees to withstand attack by this species as well as by other wood-boring insects. It is important to remember that thrifty trees are less liable to attack than sickly or stunted ones and injury is best avoided by the maintenance of trees in a vigorous condition of growth.

THE RED-SHOULDERED SHOT-HOLE BORER.[1]

The red-shouldered shot-hole borer infests dead or dying pecan limbs, into which it bores for a considerable depth. The borings or frass of the larvæ are very fine and sawdust-like in appearance, and are firmly packed or compressed within the galleries, which run with the grain of the wood. Upon attaining full growth the larvæ pupate some time during the fall or spring, and the beetles emerge during the spring months. Beetles are sometimes found during the early winter in the larval galleries, in which they remain until warm weather begins. The beetles invariably make their way out at right angles to the larval galleries, and emerge through circular holes in the bark, as is shown in figure 48.

According to Mr. C. A. Reed, Nut Culturist in the Bureau of Plant Industry, trees so severely cut back for topworking or other purposes that the trunk becomes saturated with sap and the sap cells ruptured are fairly certain to become infested with shot-hole borers. It has been observed by some that not infrequently the borers are charged with being responsible for the unhealthy and apparently diseased condition of the tree, whereas actually the diseased condition of the trunk is responsible for the presence of the insects.

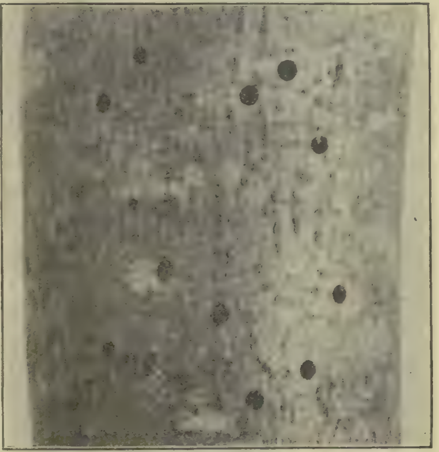

FIG. 48.—The red-shouldered shot-hole borer ([*Sinoxylon*] *Xylobiops basilaris*): Exit holes of adult beetles in pecan limb.

The beetle is black and has small punctures over the greater part of its body. The wing covers at the base or shoulder are reddish and at the tip or posterior end they are obliquely cut off, the edge of the cut being armed with three conspicuous teeth.

CONTROL MEASURES.

Since the insect attacks, as a rule, only dead or dying pecan wood, it is not to be considered a serious pest. Occasionally it attacks rather healthy trees, but it never causes any serious damage to them, since the larvæ can not subsist on wood containing a good flow of sap. As a protection against this insect, as well as against the more injurious wood-boring species, all dead trees and prunings should be removed from the orchard promptly and burned. Moreover, the trees should be kept in vigorous growing condition by practicing good orchard management.

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[1] (*Sinoxylon*) *Xylobiops basilaris* Say.

THE BELTED CHION.[1]

The belted chion, in its larval state, attacks the pecan and hickories as well as other trees, forming long galleries in the trunk or limbs of weakened or dead trees. The galleries (fig. 49) are excavated to a considerable depth in the heartwood, in which they run in the same direction as the grain. The larva is a yellowish white, round-headed borer, with brown head and black jaws. Upon attaining its full development it changes to a pupa within its gallery and the adult beetle in emerging cuts a large circular exit hole through the bark (fig. 50). The beetles make their appearance any time from March to September, as has been determined from rearing records.

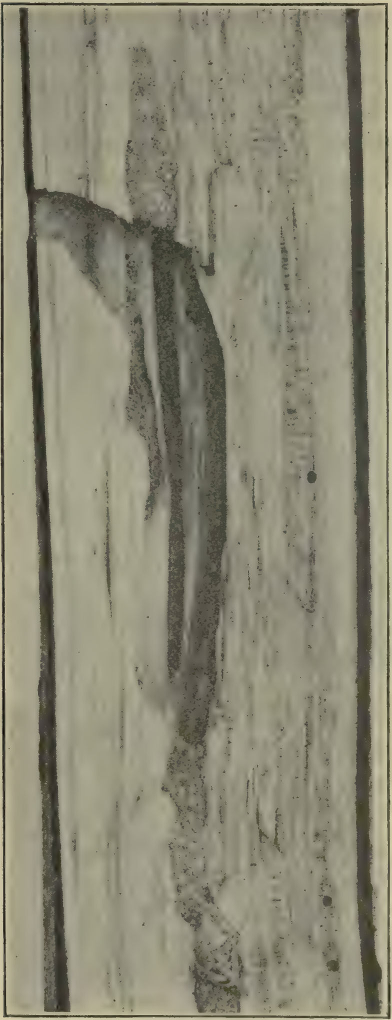

FIG. 49.—The belted chion (*Chion cinctus*): Larval galleries on pecan limb.

The size of the beetles varies, the length being from two-thirds to a little more than an inch, and in the males the antennæ, or feelers, are more than twice the length of the body. The color is light brown, usually with a short, oblique, dull band near the base of each wing cover, but in some specimens the bands are absent. Each wing cover bears two slender, conspicuous spines at its tip, and on each side of the thorax is a short, prominent spine. (See figs. 51 and 52.)

CONTROL MEASURES.

About all that is necessary to prevent injury to the pecan orchard from this pest is to remove dying trees or dead wood promptly and destroy the same by burning, as it is well known that this species prefers to breed in such material.

THE HICKORY TWIG-GIRDLER.[2]

The hickory twig-girdler is more or less familiar to all pecan growers and is an insect that is frequently the subject of inquiry. This spe-

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[1] *Chion cinctus* Drury.

[2] *Oncideres cingulatus* Say.

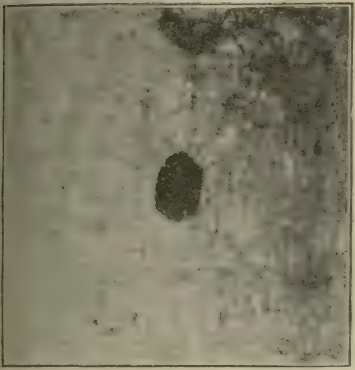

FIG. 50.—The belted chion: Exit hole of beetle.

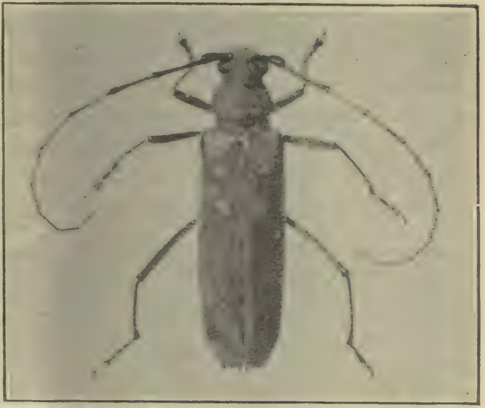

FIG. 51.—The belted chion: Adult female beetle. Enlarged.

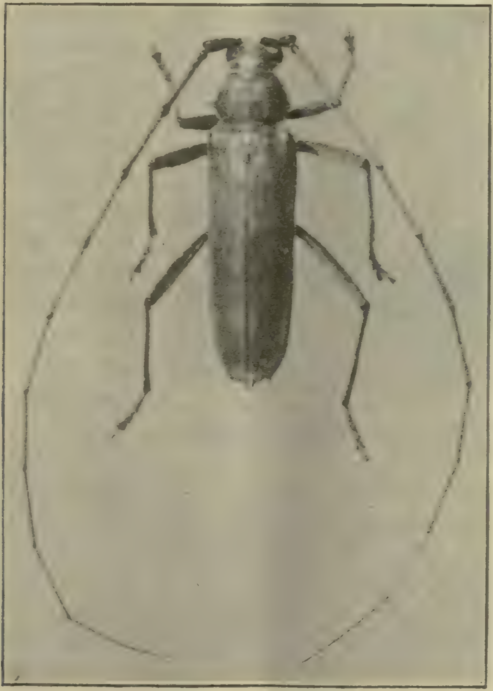

FIG. 52.—The belted chion: Adult male beetle. Enlarged.

cies is accountable for the wholesale cutting off or pruning of pecan twigs, this injury being often conspicuous during the late summer and early fall. This beetle is found over a wide range of territory, occurring in most of the Eastern, Central, and Southern States, but in its more northern distribution the extent of its depredations is not very great. In the pecan-growing sections of the South it ranks as a first-class pest because of the excessive severing of branches from pecan orchard and nursery trees by the adult beetles. Besides attacking the pecan, this species has been reported as damaging the hickory, persimmon, oak, walnut, elm, maple, locust, linden, and various pome and stone fruits, including the apple, pear, quince, cherry, peach, and plum, as well as orange trees and rosebushes. In the South, however, it seems to confine its attacks, for the most part, to the pecan, hickory, and persimmon.

When the beetles occur in abundance they are capable of doing much damage by severing branches for the purpose of egg-laying. It is not uncommon to see the ground under pecan or hickory trees literally covered with twigs that have been cut off by the beetles, and twigs often accumulate in the tree tops in conspicuous bunches (fig. 53). By the severance of the tips of the branches the fruiting area of the tree is greatly lessened or reduced and the nut crop indirectly affected for the following year, and perhaps for a longer period. This type of injury, besides affecting the nut production, causes the development of many offshoots, which destroy to some extent the symmetry of the tree. Pecan nurseries growing adjacent to a badly infested territory often suffer great loss from the girdling of the terminal branches of the nursery trees.

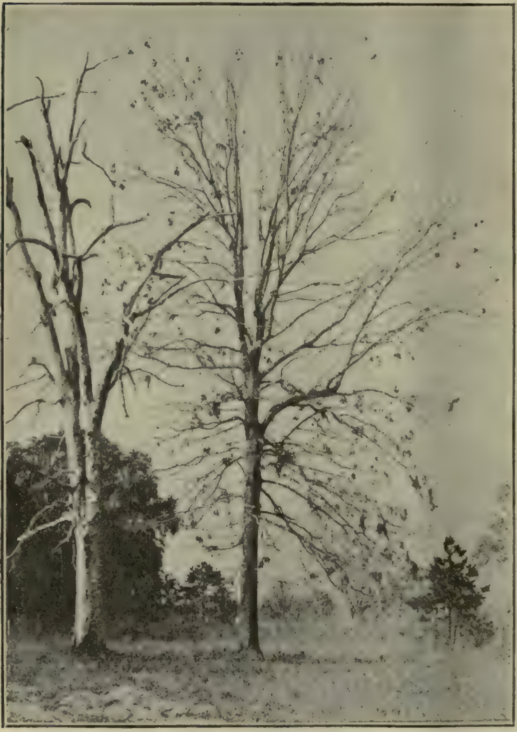

FIG. 53.—The hickory twig-girdler (*Oncideres cingulatus*): Bunches of cut-off twigs caught in branches of hickory tree.

DESCRIPTION, SEASONAL HISTORY, AND HABITS.

The beetles (fig. 54; fig. 55, *a*) range in length from one-half to five-eighths of an inch, the female being larger and more robust than the male. They have long antennæ or feelers; those of the males are considerably longer than the body, but those of the female are only a trifle longer than the body. The body is subcylindrical, and the general color is grayish brown, there being a rather broad ashy band or belt extending over the middle of the wing covers. The thorax is about the same color as the ashy band, but the head is more or less reddish. Upon close inspection it will be observed that the wing covers are ornamented with many yellowish or straw-colored spots.

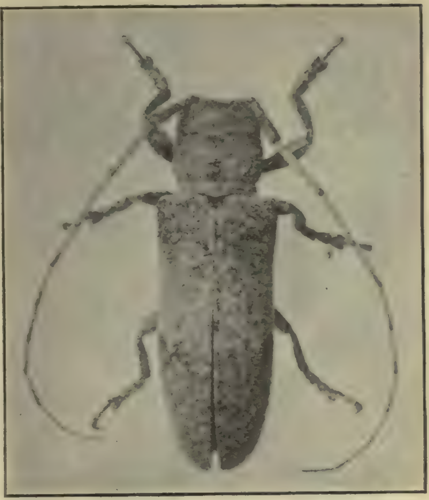

FIG. 54.—The hickory twig-girdler. Adult, or beetle. Enlarged.

The eggs, which are always deposited in the severed branches, are white, elongate oval in shape, and about one-tenth of an inch in length.

The beetles, which begin to make their appearance in pecan orchards by the last of August or early in September, have very interesting habits. It is only the female of the species that cuts off the twigs, but both sexes feed more or less upon the tender bark and wood of the tips of the branches. The branches apparently are severed by the female in order that congenial conditions may be provided for the development of the larvæ, which are unable to subsist on wood containing sap, as has been determined definitely by field observations. It has been observed that the female in girdling does not make a complete circle at once, but cuts section by section until the entire twig has been girdled. The girdling extends through the bark and well into the wood, leaving only a narrow portion of the heartwood untouched. (See fig. 55, *c*.) Usually the weight of the branch, with the assistance of the wind, causes it to bend down or break off.

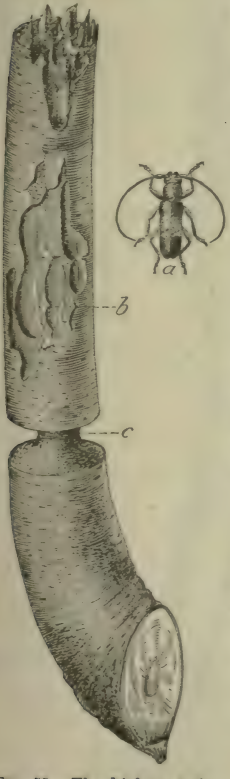

FIG. 55.—The hickory twig-girdler: *a*, Beetle; *b*, larval mines in bark and outer wood; *c*, girdling work of adult. (Webb.)

The eggs are laid during or after the cutting process, but never before the beetle has cut at least one section. They are inserted singly beneath the bark, or slightly into the wood, near a

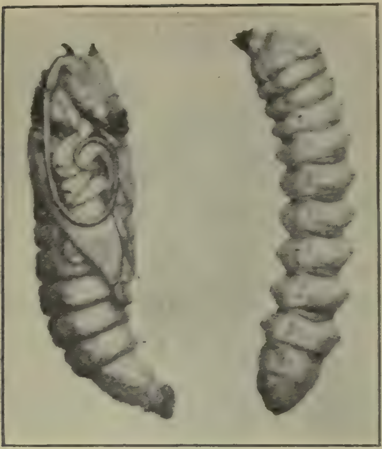

FIG. 56.—The hickory twig-girdler: Pupa at left, larva at right. Enlarged.

bud scar or adjacent to an offshoot. Usually they are deposited in the main stem of the branch, but if the branch is of a good size some eggs are to be found occasionally in offshoots. After the insertion of the eggs in the twig the puncture is sealed with a shiny, gummy substance, and the beetle then scars the twig for a short distance below the egg puncture. The number of eggs per twig may range from 3 to 40, although occasionally a severed branch without any eggs is found. The egg stage lasts about three weeks.

The larvæ (fig. 56, at right), which are whitish, legless grubs, make little growth during the fall or winter months, but with the advent of warm weather in the spring they grow very rapidly. In making their tunnels in the twig (fig. 55, *b*; fig. 57) they work usually toward the severed end and feed only on the woody fibers, leaving the bark intact. During the late spring or early summer most of the larvæ[1] make a few circular holes in the bark, from which they cast out pellets of frass and excrement. Just prior to transformation to pupa (fig. 56, at left) each larva closes the end of its gallery with shredded shavings, making the pupation quarters, from which the adult emerges by gnawing a more or less circular hole in the bark.

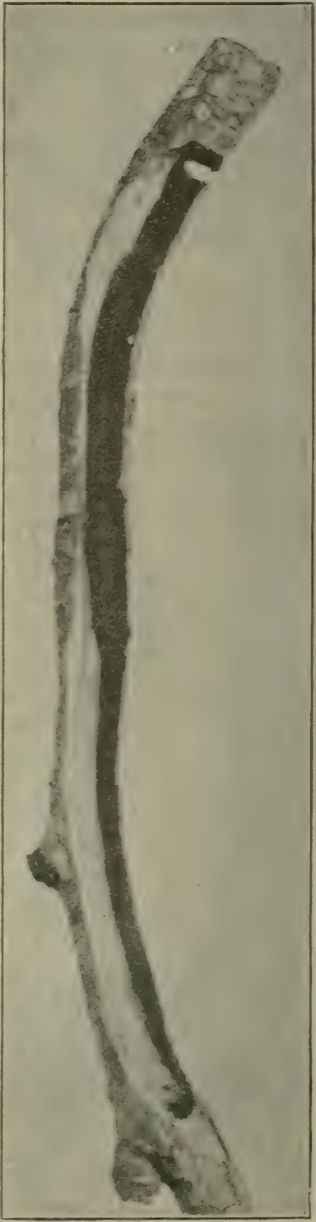

FIG. 57.—The hickory twig-girdler: Larval burrow in cut-off pecan twig.

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[1] A few larvæ may not transform until the second season.

As stated before, the beetles begin to make their appearance in the pecan orchards about the last of August, and they may be found continuing their girdling operation until cold weather.

CONTROL MEASURES.

For the control of this pest all that is necessary is to gather the severed branches and burn them in the fall or winter. Care should be exercised to collect all branches from the ground, as well as those that may be lodged in the trees. By following this procedure all the eggs and larvæ which would otherwise develop into beetles the following summer will be destroyed, and thus the source of infestation will be eliminated. Pecan orchards that are growing adjacent to native hickory or persimmon trees will be found to be worst infested, because, as has been stated, this insect breeds abundantly in the severed branches of such trees. Under such conditions it would pay, perhaps, to destroy the branches cut from the hickory and persimmon trees immediately adjacent to commercial plantings of pecans.

THE OAK PRUNER.[1]

During the fall and winter twigs or branches pruned by the larvæ or grubs of the dark-brown beetle known as the oak pruner (fig. 58) are to be found under pecan trees, as well as under oak, hickory, and various other forest, shade, and fruit trees. This insect does not especially favor the pecan, but seems to show a preference for various oaks. Although this insect occurs from New England westward to Michigan and southward to the Gulf States, it is seen too rarely in sufficient numbers in its extreme southern distribution to be ranked as a serious pest. In the North, however, serious injuries are sometimes caused by its pernicious pruning habits.

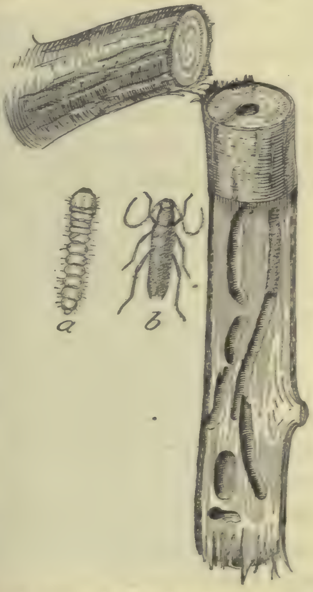

FIG. 58.—The oak pruner (*Elaphidion villosum*): *a*, Larva; *b*, adult; pruned twig and larval mines at right.

In the case of the pecan twig-girdler the twigs are cut off by the female beetle, but with the oak pruner the larvæ amputate the branches by gnawing a circular groove in the wood, leaving only the bark intact. The branches so amputated are usually brought to the ground by the first strong wind, or, in some instances no doubt, by the weight of the branch itself. The end of the severed branch presents a *smoothly cut* surface (see fig. 58), near the center of which will be seen a more or less oval opening plugged with fine shavings and sawdust. By way of contrast it may be stated that the end of the twig that is cut off by the pecan twig-girdler always presents at its center a more or less jagged surface.

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[1] *Elaphidion villosum* Fab.

In brief, the seasonal history is as follows: The beetles (see fig. 58, *b*) usually appear during the spring or early part of the summer, and the eggs are deposited in the leaf axils of the smaller twigs of living trees. Upon hatching, the larva feeds upon the wood immediately under the bark, but later it bores into the heartwood, where it makes an oval gallery several inches in length. (See fig. 58, at right.) In the fall it cuts away the wood at the end of its gallery in such a manner that the wind causes the twig to snap off. The larva (fig. 58, *a*) then proceeds to stop up the end of its channel with coarse shavings. In the larval burrow within the fallen branch the pupa is formed, either in the fall or early spring, and during the spring or early summer the beetle makes its appearance in the pecan orchards. Occasionally specimens of adults can be found in the pecan orchards as early as April.

CONTROL MEASURES.

The remedy for this species is the same as that for the pecan twig-girdler and consists in gathering the severed branches and burning them during the winter.

SCALE INSECTS.

Fortunately for the pecan grower it is seldom, if ever, necessary for him to spray his orchard trees for the control of scale insects, as is the common practice in the growing of apples, peaches, and other fruits. The pecan is not immune to attack by insects of this group, but because of the limited infestation scale insects have not up to this time (1917) come into the category of pests of first importance. When scale insects are found to be present on pecan trees specimens should be sent to the Bureau of Entomology for observation or to the State agricultural experiment station.

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THE GIPSY MOTH AND THE BROWN-TAIL MOTH AND THEIR CONTROL

A. F. BURGESS
In Charge of Gipsy Moth and Brown-tail Moth Investigations

Female gipsy moths depositing eggs on tree trunk.

FARMERS' BULLETIN 845

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. September, 1917

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THE GIPSY MOTH and the brown-tail moth are among the most serious and destructive of the insects injuring tree growth that have been introduced into the United States.

About one-third of the area of New England is now infested with these pests.

Marked progress in checking their spread has resulted from the field and quarantine work now being carried on and from the introduction of parasites and natural enemies, and the increase in the diseases that attack them has served to lessen the damage.

The work of combating these insects is being carried on by each of the New England States and by the United States Bureau of Entomology.

Hand methods generally employed against the gipsy moth are treatment of the egg clusters with creosote, banding the trees with burlap or a suitable tree-banding material, and spraying. These are described on pages 15–19.

Hand methods applicable against the brown-tail moth consist in cutting off and burning the winter webs before the caterpillars emerge in April and spraying with arsenate of lead, as described on pages 14–15, before the middle of August. Where the infestation is very slight the cutting and burning of the webs will be more satisfactory than spraying.

Orchards can be protected fully from these pests by a system of management that will cost very little in addition to the expense required for protection against other orchard insects. See pages 19–21.

The expense of caring for infested city and park trees is somewhat greater than for orchards, but practical measures can be adopted, as shown on page 21, and their cost will not be prohibitive.

The control of the gipsy moth and the brown-tail moth in forests is extremely difficult, owing to the relatively small amount of money that any owner can afford to expend in protecting his woodland. He should accept the advice of a State, local, or Federal official familiar with these insects and their control, who, after an examination, would be able to suggest the measures most applicable in the particular case. The general principles involved in woodland control of the brown-tail moth are explained on page 24, and those for the gipsy moth on pages 22–24.

THE GIPSY MOTH[1] AND THE BROWN-TAIL MOTH[2] AND THEIR CONTROL.

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IN 1869 a number of egg clusters of the gipsy moth, an insect pest destructive in Europe, were brought from France to Medford, Mass., by a naturalist who was carrying on experimental work with insects. Later in the season some of the caterpillars escaped, and although none was found in the vicinity during the next few years, enough specimens survived to enable the species to establish itself. In the summer of 1889 this insect became so abundant that fruit and shade trees in the neighborhood were completely defoliated, and the caterpillars swarmed over the trees and into the houses and became a serious nuisance. Valuable trees were lost and property values in that section depreciated.

For about 10 years effective work against the gipsy moth was carried on by the State of Massachusetts, and during this period the insect was kept under control. The work was discontinued in 1900, but the species had become so abundant and had caused such widespread injury by 1905 that systematic work was renewed by the State for the protection of tree growth in the infested area. This work has been continued up to the present time, and as the insect has spread to other New England States it has become necessary to institute more extensive control measures.

In 1906, after the gipsy moth had become established in New Hampshire and Rhode Island, as well as in Massachusetts, an appropriation was made by Congress for suppressing it, and the Secretary of Agriculture was authorized to take all possible measures to prevent its spread. Since that time work has been carried on each year. The area now known to be infested is shown in figure 1.

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[1] *Porthetria dispar* L.

[2] *Euproctis chrysorrhoea* L.

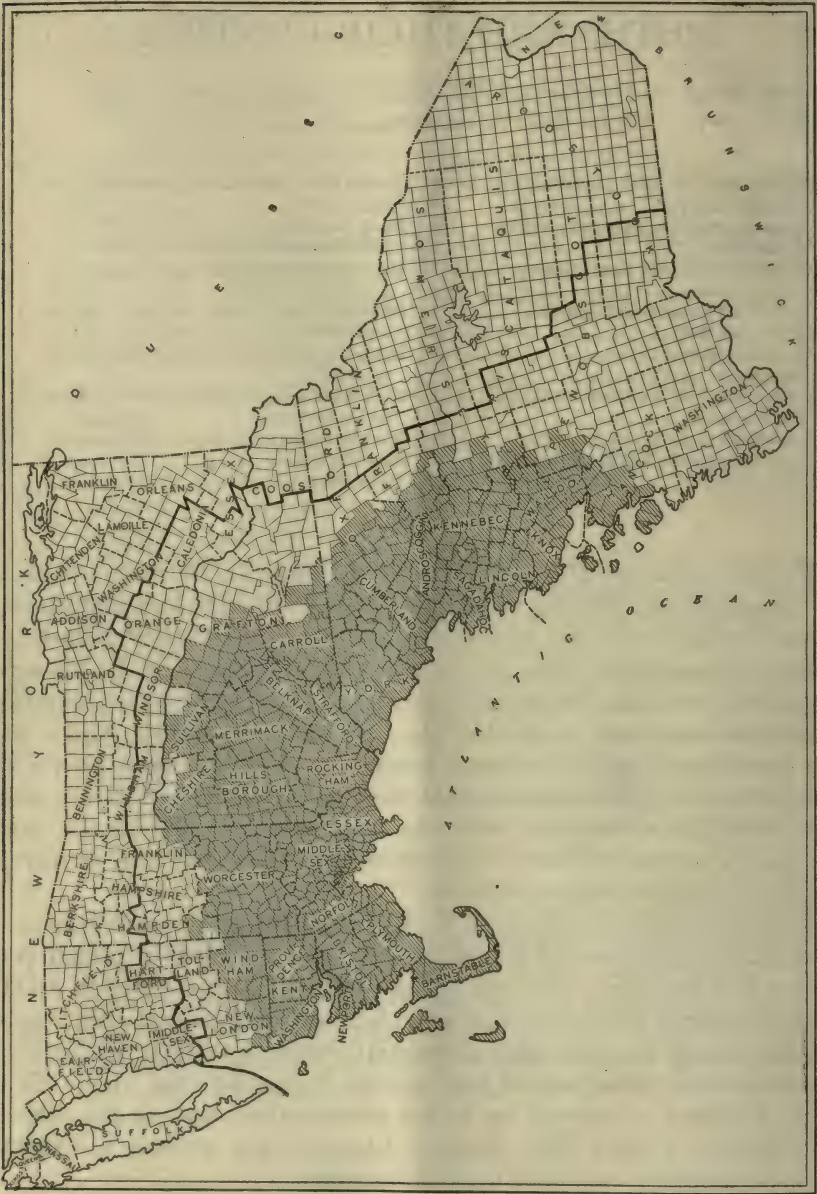

FIG. 1.—Map showing area infested by and quarantined for the gipsy moth and the brown-tail moth in New England, 1917. Shaded area infested by the gipsy moth; area east of heavy line infested by the brown-tail moth.

The brown-tail moth was first found in the United States in Somerville, Mass., during the summer of 1897 and was undoubtedly introduced several seasons before that time on imported nursery stock. The work of preventing damage by this insect was undertaken by the State of Massachusetts soon after the pest was discovered. This species occurs in many sections of Europe and often is seriously injurious. It spreads rapidly because the females are able to fly long distances. Figure 1 shows the area in New England which is now infested by the brown-tail moth. Suppressive measures by the New England States and by the Federal Government have been directed against this insect as well as against the gipsy moth.

This bulletin describes briefly the seasonal history and habits of these two species and suggests the best methods for their control, determined and adopted as a result of many extensive experiments.

THE GIPSY MOTH.

SEASONAL HISTORY.

(Fig. 2.)

In the course of its life the gipsy moth passes through four stages—namely, the egg, the larva or caterpillar, the pupa or resting stage, and the adult or moth.

The eggs.—The female gipsy moth deposits a cluster containing 400 eggs or more, which she covers with buff-colored hairs. Most of the egg clusters are laid during the month of July and hatch about the time the leaves begin to appear the following spring. They are deposited on the underside of branches of trees, on tree trunks, under loose bark, or in cavities in the trunks or branches, and are sometimes placed on stones or rubbish and in a variety of situations where they are concealed from view. As the female moth does not fly, egg clusters are seldom found far from the food plant upon which the caterpillars developed.

The larvæ.—The newly-hatched larvæ feed on the opening leaves, making small perforations. They grow rapidly and become full fed early in July. During this period they molt five or six times, and as they increase in size a larger proportion of the foliage is eaten, so that if the infestation is severe, trees may be stripped of foliage completely before the end of June.

The pupæ.—When full grown the caterpillars shed their skin and transform to pupæ, which are chestnut brown in color and provided with tufts of yellow hairs. They remain in this dormant stage for about 10 days, after which the adult insects emerge.

The adults.—The male moth is dark brown, with black wing markings, and flies well. The female is white, with black markings on the wings, and because of the weight of the abdomen does not fly. After mating the females begin depositing eggs.

MEANS BY WHICH THE GIPSY MOTH IS SPREAD.

Egg clusters of the gipsy moth that are deposited on trees, lumber, stone, or other products that are likely to be shipped may be carried long distances and cause the establishment of new colonies of the insect. Spread in this way is prevented by inspection of such products before they are shipped. Caterpillars of this insect may be spread for limited distances by carriage on moving objects, such as

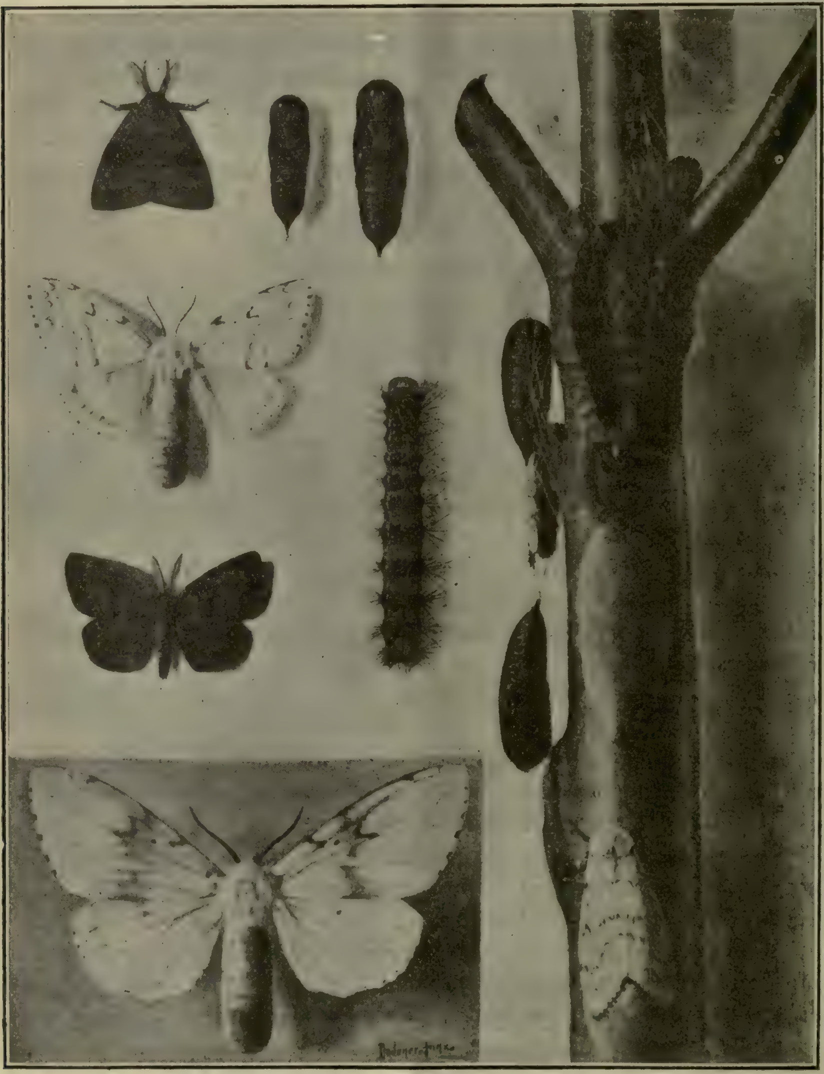

FIG. 2.—Different stages of the gipsy moth (*Porthetria dispar*): Egg mass on center of twig; female moth ovipositing just below; female moth below, at left, enlarged; male moth, somewhat reduced, immediately above; female moth immediately above, somewhat reduced; male moth with wings folded in upper left; male chrysalis at right of this; female chrysalis again at right; larva at center.

trains, horse-drawn vehicles, or automobiles. The danger of such spread is very limited if the roadways are kept free from severe infestation, and under present conditions in the infested territory danger of spread in this way is not great. New colonies are started principally by the spread of newly hatched caterpillars. Experiments have shown that under favorable conditions these caterpillars may be blown by the wind. The temperature must be high enough for the caterpillars to be active and the stronger the wind the greater the probability of their being carried long distances. It has been demonstrated that caterpillars have been carried more than 20 miles in this way, and specimens have been caught in the air 50 feet above the ground, although probably they are carried much higher than this. It is necessary for the temperature to range above 65° F. and for the wind velocity to be 8 miles or more per hour, in order that wind spread of small caterpillars may result.

FOOD PLANTS.

The food plants most favored by the gipsy moth are the apple, the different species of oak, gray birch, alder, and willow. In cases of bad infestation nearly all deciduous trees are injured to a greater or less extent, with the exception of ash. Hickory is not a favored food plant, although the foliage occasionally shows severe feeding. Chestnut will not support the gipsy moth when the caterpillars are in the first stage, and pine will not support the first two stages; but if other food plants are present severe injury may result from feeding by the larger caterpillars. Beech is sometimes fed upon freely, and occasionally the trees are defoliated; and the same is true of poplar.

INJURY CAUSED BY THE GIPSY MOTH.

Unless reduced in numbers by natural enemies, or by the application of control measures, the gipsy moth is capable of causing enormous injury to tree growth. In the area in New England which has suffered most from this insect thousands of trees are dead as a result of defoliation. (See fig. 3.) Many areas were cut before the trees were mature and the wood sold at a loss on account of damage caused by this insect. Apple and oak have been injured most, but pine and other coniferous trees mixed with deciduous growth have suffered severely.

It is undoubtedly true that many oak trees which have been weakened severely as a result of defoliation by the gipsy moth and the brown-tail moth have failed to recover because of the attacks of certain wood-boring insects. The species which has caused most damage in this way is a beetle[1] known as the two-lined chestnut borer, the larva of which feeds beneath the bark of injured trees.

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[1] *Agrilus bilineatus* Weber.

NATIVE ENEMIES.

Few insect enemies of the gipsy moth native to New England cause any noticeable reduction in its numbers. This is shown by the fact that between the years 1900 and 1905, when no systematic effort was made to suppress the insect, alarming injury resulted, and native insect enemies did not increase to any marked degree. The same is true of the work of native insectivorous birds. While they undoubtedly feed to some extent on gipsy-moth caterpillars, there is no case on record where they have been able to control the species. The

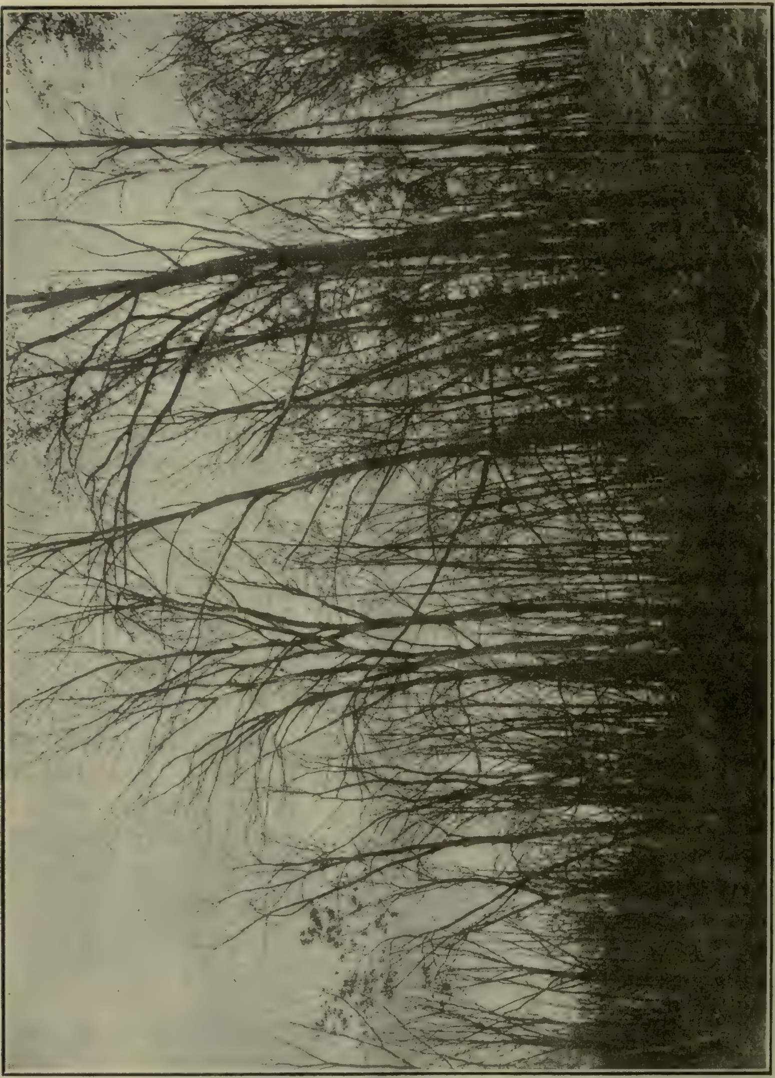

FIG. 3.—Dead and defoliated woodland resulting from gipsy-moth attack.

wilt disease, however, which possibly may have occurred in this country for many years, has become sufficiently prevalent to be a prominent factor in natural control.

INTRODUCED PARASITES AND ENEMIES.

In 1905 an effort was made by the State of Massachusetts, in cooperation with the Bureau of Entomology, United States Department of Agriculture, to introduce the parasites and natural enemies of the gipsy moth from its native home in Europe and Japan. Since that time a large amount of parasitized material has been received and as a result several natural enemies have become firmly established in this country and are assisting in bringing about the control of the species. The enemies which have become established and are at present destroying the largest number of gipsy-moth caterpillars and pupæ are a beetle,[1] a tachinid fly,[2] which is also a parasite of the brown-tail moth and attacks many native injurious caterpillars; and a minute four-winged wasplike parasite,[3] which attacks small gipsy-moth and small brown-tail moth caterpillars. Two tiny parasites of the eggs, one of which[4] was imported from Japan and the other[5] secured from Europe, have also been colonized in a portion of the infested area and are valuable additions to the natural enemies of this insect. Several other parasites have been introduced and are established in this country, but they have not increased sufficiently to be classed as important factors in gipsy-moth control.

The work of the natural enemies of the gipsy moth, including the imported parasites, the Calosoma beetle, and the wilt disease, has served greatly to reduce the numbers of the insect in many badly infested localities. This is particularly true in the region which has been infested longest, and it is hoped that when these enemies of the moth have become established in larger numbers over the entire infested territory the insect will be much less a destructive factor than it is at present. Colonization of most of these species has been carried on throughout the entire area but much remains to be done in colonizing the egg parasites. The records at the gipsy moth laboratory at Melrose Highlands, Mass., indicate that all of the species of insect parasites mentioned have been gradually increasing in the field during the past few years and the results of their work are very noticeable in certain restricted areas. Until these natural enemies become more abundant than they are at present throughout the entire infested territory it will be necessary to employ the most effective mechanical methods for restricting the spread and curtailing the increase of this species.

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[1] *Calosoma sycophanta* L.

[2] *Compsilura concinnata* Meig.

[3] *Apanteles lacteicolor* Vier.

[4] *Schedius kuanae* How.

[5] *Anastatus bifasciatus* Fonsc.

THE BROWN-TAIL MOTH.

SEASONAL HISTORY.

(Fig. 4.)

As is the case with all other moths, the brown-tail moth in its development is first an egg, then a larva or caterpillar, then a pupa, and finally an adult moth.

The eggs.—The female brown-tail moth deposits a small cluster of eggs on the underside of a leaf. These eggs usually are laid in July and are covered with brown hairs taken from the body of the female. Hatching begins about the 15th of August.

The larvæ.—The newly hatched larvæ of this insect feed on the epidermis of the leaf and after molting once or twice begin to construct a winter web. This is made by drawing together several terminal leaves and securely fastening them by silk which is secreted by the caterpillars. The larvæ from one or more egg clusters live and feed in common, and as cold weather approaches they retire to the web, in which they remain during the winter. In the spring these larvæ leave the web as soon as the buds begin to develop and feed upon the bud scales and small leaflets. They become full-grown about the middle of June.

The pupæ.—After the caterpillars finish feeding they spin loose silken cocoons and pupate within them. These cocoons sometimes are constructed separately, but in many cases large numbers of them are spun in a single mass. About two weeks are spent in the pupa state.

The adults.—Emergence of the moth usually begins the first week in July. The adult brown-tail moth is pure white. The abdomen of the female is much larger than that of the male, but in both sexes the tip of the abdomen is covered with dark-brown hairs. These moths are attracted to strong light, such as electric arc lights, and as they fly at night it is often possible to secure many specimens around the arc lights in cities and towns during the first half of the month of July.

FOOD PLANTS.

The caterpillars of the brown-tail moth commonly feed on apple, pear, plum, oak, and willow, and sometimes they are found in considerable numbers on elm, maple, and rose and in smaller numbers on other common deciduous trees and shrubs. They never attack conifers and are seldom found on hickory, ash, chestnut, or birch.

INJURY CAUSED BY THE BROWN-TAIL MOTH.

The principal injury caused by the brown-tail moth is due to the feeding habits of the larvæ in the spring. If the infestation is bad, the caterpillars often are numerous enough to devour the leaves as fast as the trees are able to develop them. As the webs are made on the terminals, the growth of the trees often is checked severely. In heavy infestations trees may be stripped completely (figs. 5, 6), but as the larvæ become full-grown during the first part of June, the trees usually have an opportunity to refoliate before midsummer. The young larvæ that hatch in August frequently skeletonize the leaves

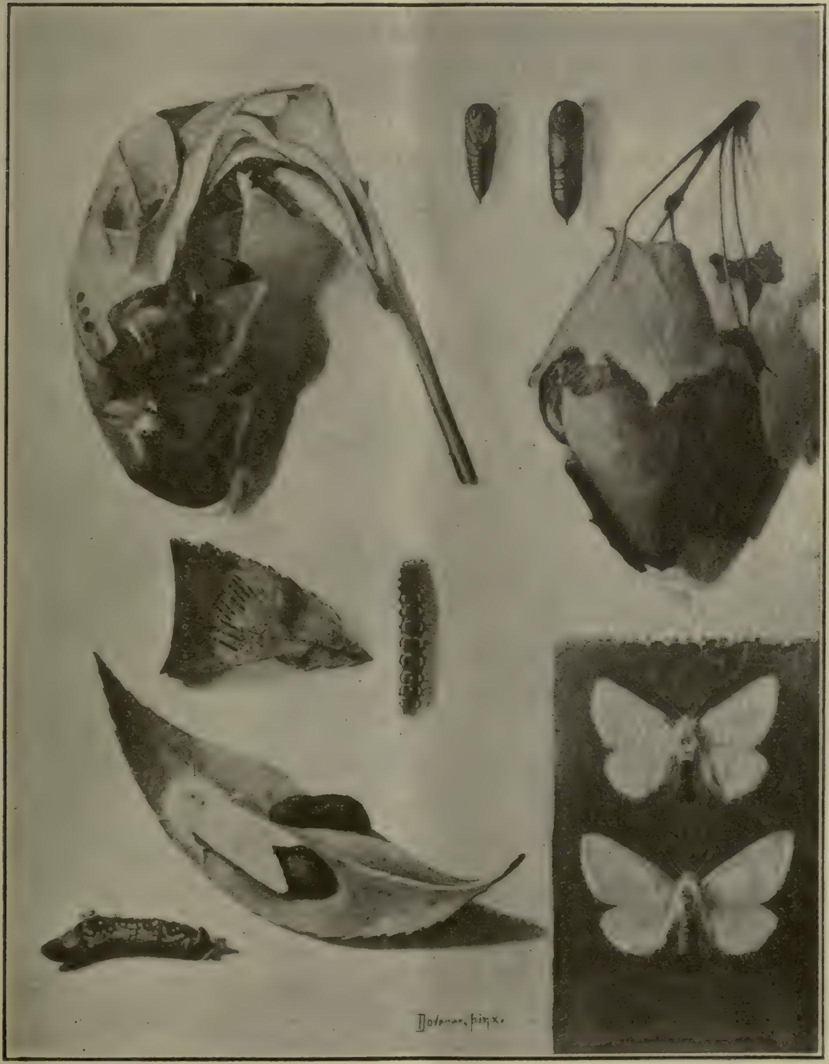

FIG. 4.—Different stages of the brown-tail moth (*Euproctis chrysorrhoea*): Winter nest at upper left; male and female adults, lower right; cocoon in leaves, upper right; male and female chrysalides above, male at left; full-grown larva in center, somewhat reduced; young larvæ at its left; egg mass removed from leaf, showing single eggs, at lower left; female ovipositing on leaf; egg mass also on same leaf.

to a considerable extent. This does not damage the trees seriously, as the growing period for the season is nearly completed.

The bodies of the caterpillars of the brown-tail moth are provided with poisonous hairs. A microscopic examination of these hairs shows that the edges are barbed in such a way that when they come in contact with the human skin and are pressed into the flesh, intense irritation is caused. These hairs are also hollow and contain a poisonous substance which acts on the blood corpuscles. This causes serious poisoning and severe irritation accompanied with external swelling and is known as the brown-tail rash. Persons differ considerably in their susceptibility to this poison, but many cases are reported each year in the infested region, most of which are more serious than those of ivy poisoning. Many camps and summer cottages, particularly in wooded areas, can not be occupied with any comfort during the early summer on account of the poisoning resulting from these caterpillars. If clothing is hung on the line near badly infested trees, the hairs frequently find lodgment and are brought into the houses, and later severe poisoning may result.

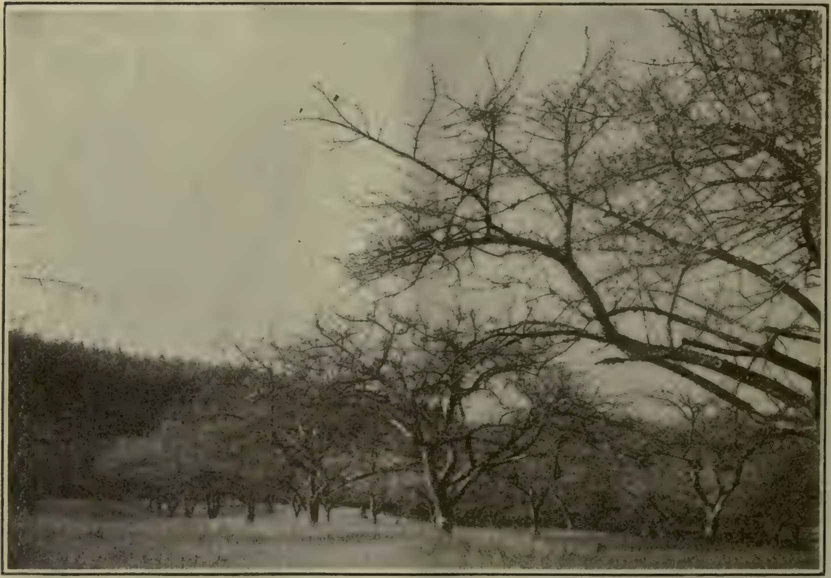

FIG. 5.—Apple trees stripped by brown-tail moth caterpillars. Note old winter webs at tops of trees.

NATIVE ENEMIES.

One of the most important natural enemies of the brown-tail moth is a fungous disease,[1] which attacks the caterpillars, particularly in the spring. It was first reported in this country by Dr. Roland

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[1] *Entomophthora aulicae.*

Thaxter in 1888. Like all diseases of this nature, the benefit derived from it is regulated largely by favorable or unfavorable weather conditions. This fungus sometimes works to a slight degree on the small caterpillars in the fall, and in some instances it is found in the winter webs. As a rule, however, the greatest mortality of caterpillars takes place in the spring, when they are nearly full-grown, and the pupæ of the moth, under the most favorable conditions,

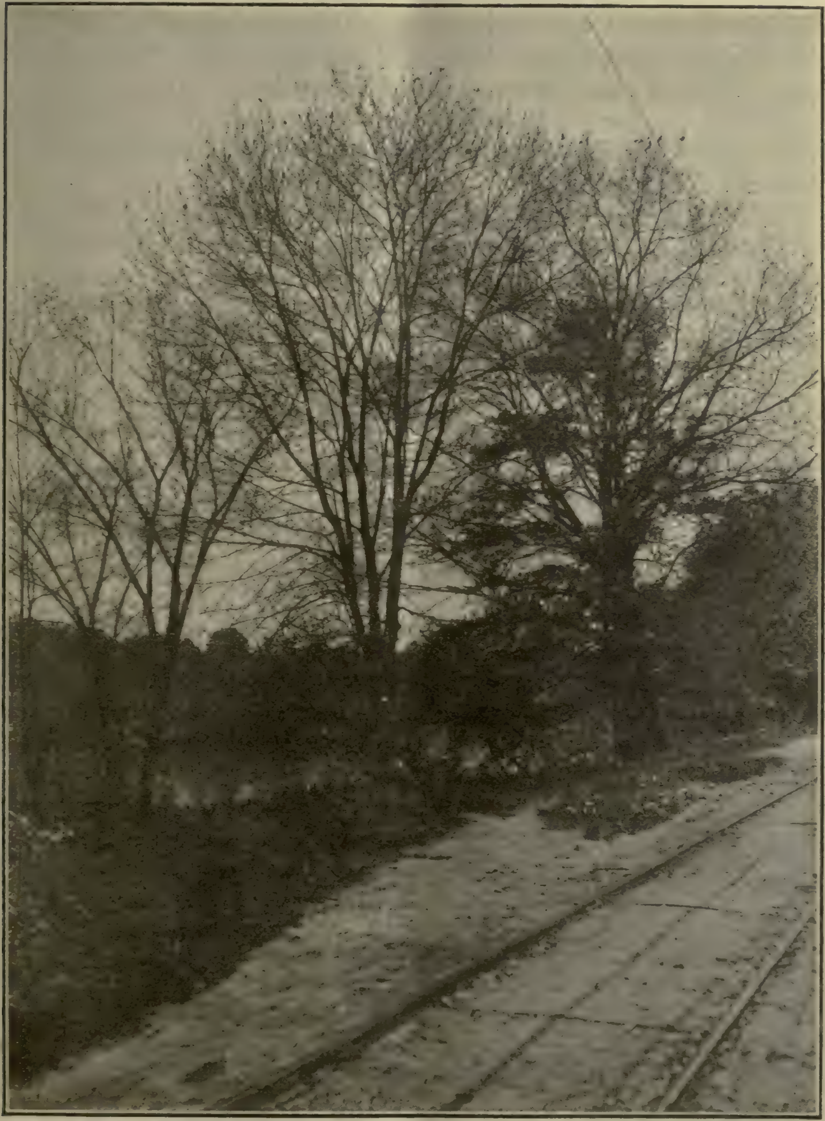

FIG. 6.—Red oak trees stripped by brown-tail moth caterpillars. Note old winter webs at tops of trees.

may be almost completely exterminated. Native parasites and predacious insects have done very little to check the increase of the brown-tail moth.

INTRODUCED PARASITES AND ENEMIES.

The parasites and enemies already mentioned as being particularly valuable for their work in destroying the gipsy moth, with the exception of the egg parasites, also attack the brown-tail moth. The Calosoma beetle[1] and its larvæ do valuable work each year in destroying brown-tail caterpillars and pupæ, and the insect parasites also attack this species in considerable numbers. Another imported parasite[2] has become established in this country and is doing excellent work. It attacks the brown-tail moth caterpillars, but not those of the gipsy moth.

Throughout the infested territory a marked decrease in the number of moths has been noted during the last two or three years. The work of the parasites has been a very important factor in this connection. In some parts of the infested territory the mortality among the caterpillars in the brown-tail webs has been very high during the winter.

HAND METHODS FOR CONTROLLING THE BROWN-TAIL MOTH.

The brown-tail moth can be controlled by cutting off the winter webs and burning them before the caterpillars begin to emerge in April. These webs should be destroyed by fire, for if they are simply cut from the tree and left on the ground the caterpillars will emerge and no benefit will result from the work which has been done.

In orchard practice it is sometimes inadvisable to cut the winter webs, for where an infestation is bad it is likely to leave a poorly shaped tree. Spraying in the spring is not a satisfactory remedy unless the infestation is very light, because the caterpillars, when they occur in large numbers, do not allow the tree to put out sufficient foliage to hold the spray material. The most effective method is to spray the trees before the middle of August, using from 6 to 10 pounds of arsenate of lead to 100 gallons of water. Before spraying operations of this sort are attempted care should be taken to determine whether the trees are well infested with egg masses of the brown-tail moth, for if the infestation is very slight it will be more satisfactory to cut and destroy the webs. If the infestation warrants, both shade, ornamental, and fruit trees may be sprayed to advantage at this time. Caution should be used, however, in spraying fruit trees, particularly if early fall varieties are to be treated. If this is to be done, a somewhat weaker spray solution may be used, provided it is applied as soon as the caterpillars begin to hatch. The foliage should be treated thoroughly, particularly the terminal shoots, and as much care as possible should be exercised not to cover the fruit. Late fall or winter varieties of fruit may be sprayed in August with arsenate of lead, using 6 pounds to 100 gallons of water, and although an occasional spot may be found on the fruit at the time of picking, no injury will result from it. In cases where only a few choice fruit trees are sprayed it is practicable to wipe the fruit before packing for sale; but this will not be necessary if care is taken to treat the terminal growth of the trees, as this is where the bulk of the egg clusters is deposited.

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[1] *Calosoma sycophanta* L.

[2] *Meteorus versicolor* Wesm.

GENERAL HAND METHODS FOR CONTROLLING THE GIPSY MOTH.

Creosote.—One of the best methods of controlling the gipsy moth is to treat the egg clusters of the insect between August 1 and April 1 with creosote, to which a small amount of lampblack has been added. This material is sold by dealers in the infested region under the name of gipsy-moth creosote. It is applied with a brush, and leaves a black residue on the clusters treated. Creosote may be obtained in small quantities from nearly all the large hardware or seed stores in the infested district.

Burlap bands.—Gipsy-moth caterpillars usually seek shelter during hot, sunny days, and if a band of burlap is attached to a tree, large numbers of them will crawl beneath it, where they may be crushed each day. Ordinarily a strip of burlap about 8 inches wide is placed loosely around a tree trunk and a piece of twine passed around the center and tied to hold it in place. After this is done the top part of the burlap is folded down so that a double shelter is made beneath it. The use of burlap bands has been discontinued during the last few years, owing to the expense involved and because of the fact that if the burlaps are applied early in the season, before the brown-tail caterpillars have pupated, an excellent place is furnished for these poisonous caterpillars to make their cocoons (see fig. 7), and severe poisoning results to the workmen. If this method is to be used at all, the burlap should not be attached to the trees until after June 15, when most of the brown-tail moth caterpillars will have pupated.

Sticky bands.—Bands of a widely known sticky substance for use in banding trees, which may be obtained on the market, may be used on tree trunks after the bark has been scraped so that the material can be applied evenly in a thin layer with a paddle. The purpose of this band is to prevent caterpillars from ascending the trees, and if the egg clusters previously have been treated, this is a very effective measure. It is necessary every week or 10 days during the caterpillar season to run a comb or other similar implement around the band in order to prevent hardening of the surface and to bring up fresh, sticky material from the part of the band near the bark. (See fig. 8.) Placing these bands on the trees prevents the caterpillars from reaching the foliage; and as the caterpillars usually mass in large numbers beneath the bands, conditions are favorable for the development of wilt disease, and the caterpillars often die in large numbers from this cause and from starvation.

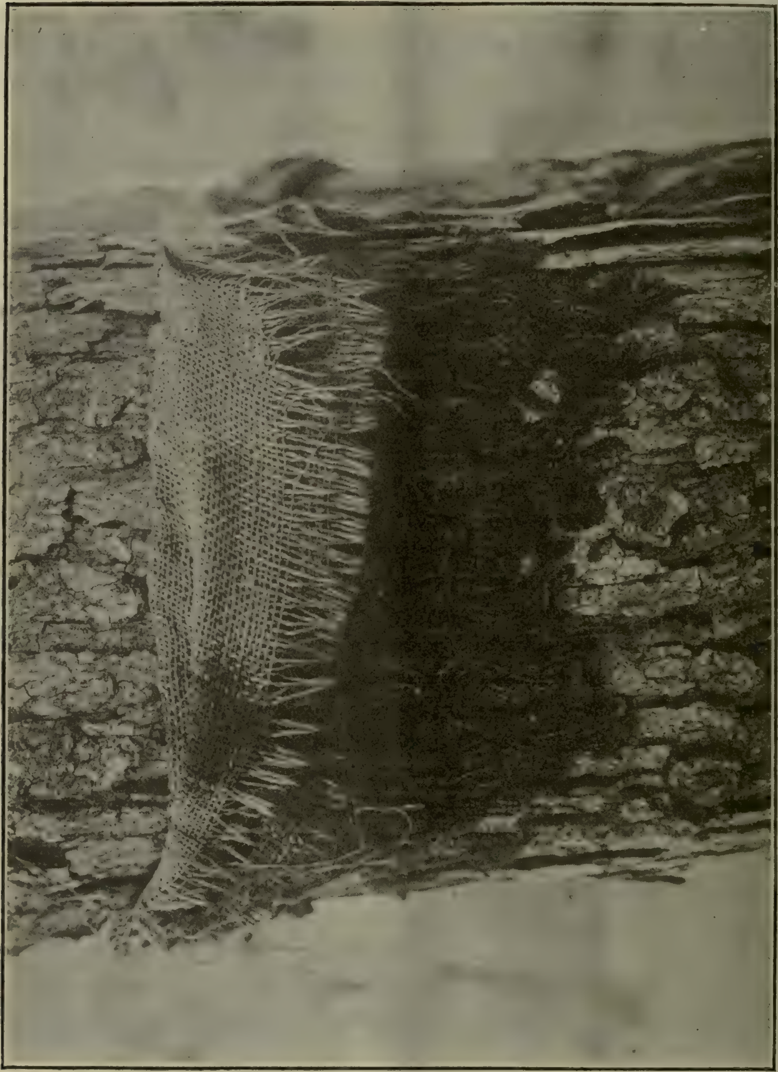

FIG. 7.—Burlap band on tree. The caterpillars beneath it are nearly all those of the brown-tail moth.

Use of tree-banding material.—A new material for banding trees has been prepared and tested by the Bureau of Entomology in cooperation with the Bureau of Chemistry. It is black and of a greasy nature and is applied to the trees with a special "gun" designed for the purpose. (Fig. 9.) A thick, narrow band is left on the tree trunk, preventing the caterpillars from reaching the foliage. This material is cheap and effective and is more easily applied than is the sticky substance mentioned in the last paragraph, because it is not necessary to scrape the trees before it is put on.

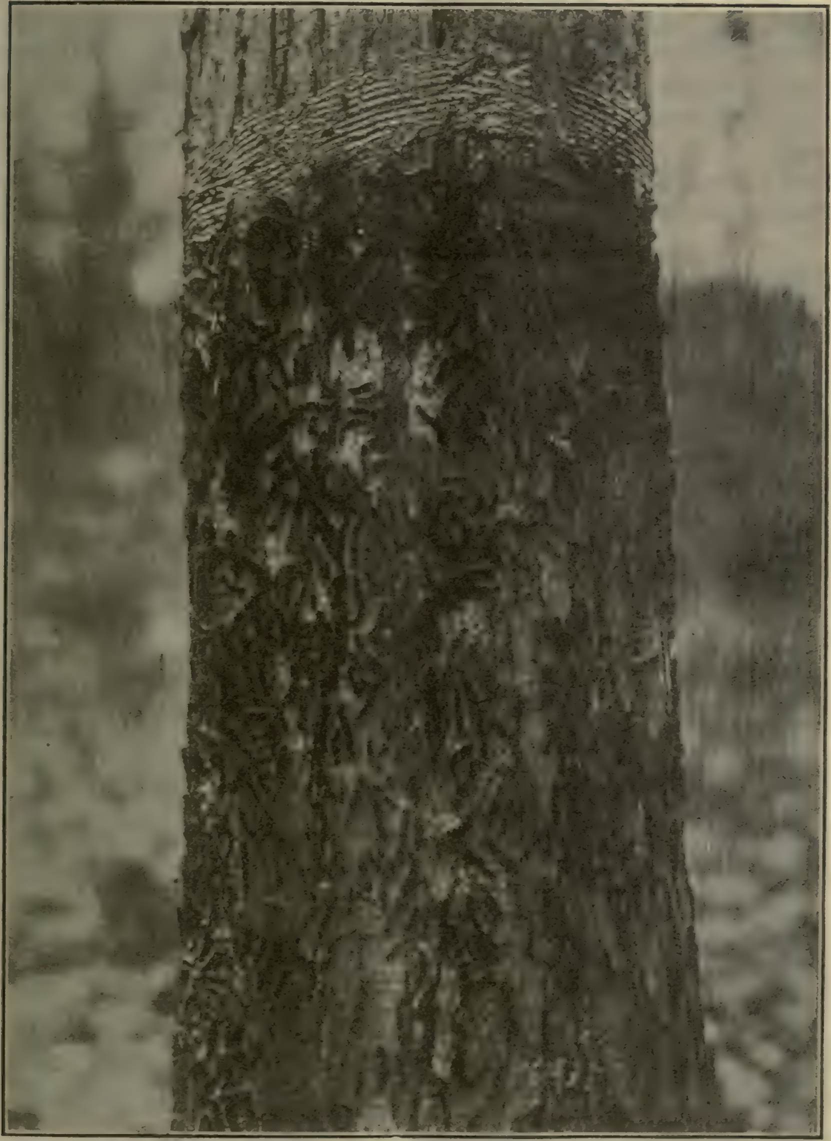

Fig. 8.—Band of sticky material. Note that the enormous numbers of gipsy-moth caterpillars are below the band, but none are above it.

Spraying.—The most effective spray for the gipsy moth is arsenate of lead paste applied to the foliage at the rate of 10 pounds to 100 gallons of water. It is necessary that the treatment be thorough and the application even, if best results are to be secured. For small operations the ordinary orchard sprayer may be used with one or more lines of hose equipped with nozzles of the Vermorel or Bordeaux type. In case large shade trees on valuable park or woodland are to be treated, however, the use of a high-power sprayer is more economical. The type that has given the most satisfactory results in the gipsy-moth work develops sufficient power to throw a solid stream of spray into the trees. The nozzle is constructed so that the stream will break into a fine mist high in the air, and this results in very satisfactory and rapid treatment. (See fig. 11.) With such a sprayer it

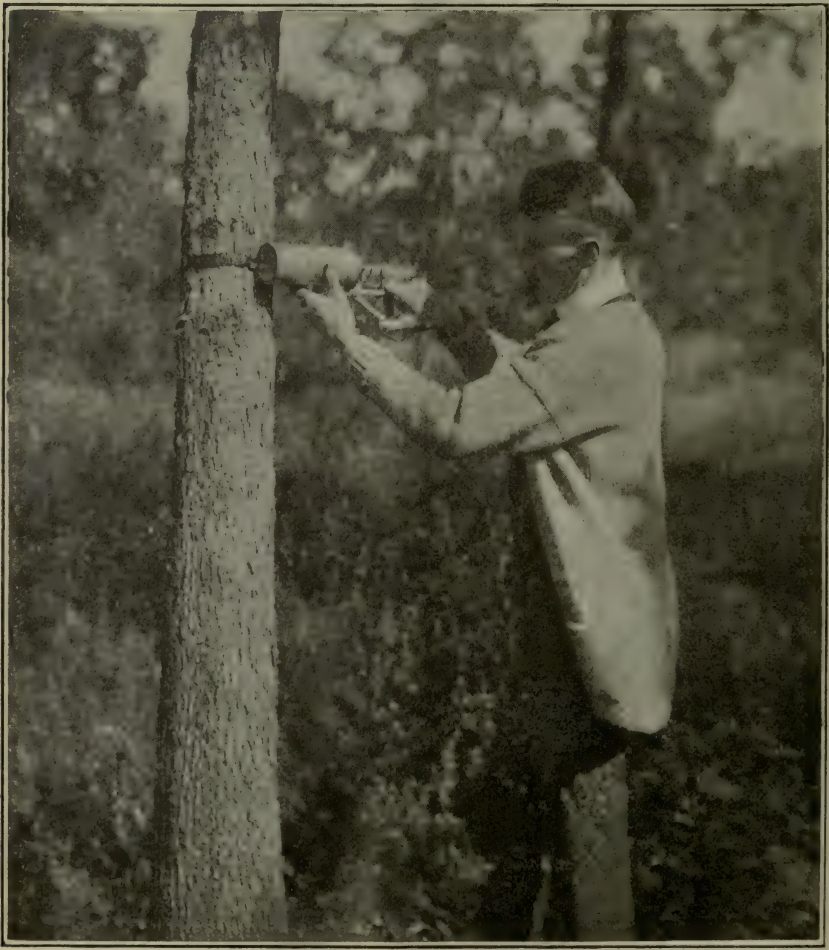

FIG. 9.—Applying tree-banding material to protect the foliage from gipsy-moth caterpillars.

is unnecessary to climb trees and use small lines of hose, which is a slow and expensive operation. A satisfactory high-power sprayer (Fig. 10) for this work should be equipped with a 10-horsepower gasoline engine and a triplex pump capable of delivering 35 gallons of liquid per minute at a pressure of from 225 to 350 pounds. This machinery, together with a 400-gallon tank, should be mounted on well-built trucks. One-inch hose is used, and by slightly increasing the pressure at the machine the spray material can be conducted through several hundred feet of this hose with the outfit mentioned without seriously reducing the nozzle pressure, which should be maintained at about 225 pounds.

By using a small device, which is attached to the nozzle and is known as a spreader, it is possible to spray low growth very satisfactorily. Fruit trees can be treated very rapidly in this way (Fig. 12).

HAND METHODS TO BE USED AGAINST THE GIPSY MOTH IN ORCHARDS.

The methods to be used for controlling the gipsy moth in orchards should be determined largely by the severity of the infestation. If only a few egg clusters are present in the orchard, early spraying, such as is applied for the codling moth after the blossoms have fallen, will be found useful, providing the amount of poison used is increased to 10 pounds to 100 gallons of water. If the infestation is more serious, a second spraying early in June, using a similar amount of poison, will be found very satisfactory. In cases where the infestation is severe it probably will be necessary to creosote egg clusters in the winter and

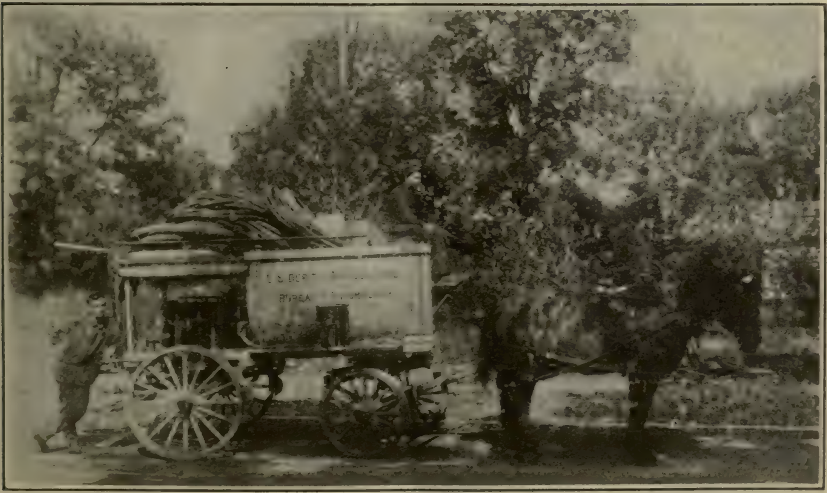

FIG. 10.—High-power sprayer.

spray in the spring if the insect is to be controlled. In any case thoroughness is a prime essential if good results are to be secured.

All poor or hollow trees should be removed, and if badly infested woodland is near by, the orchard trees should be banded with the sticky substance previously mentioned or with the new tree-banding

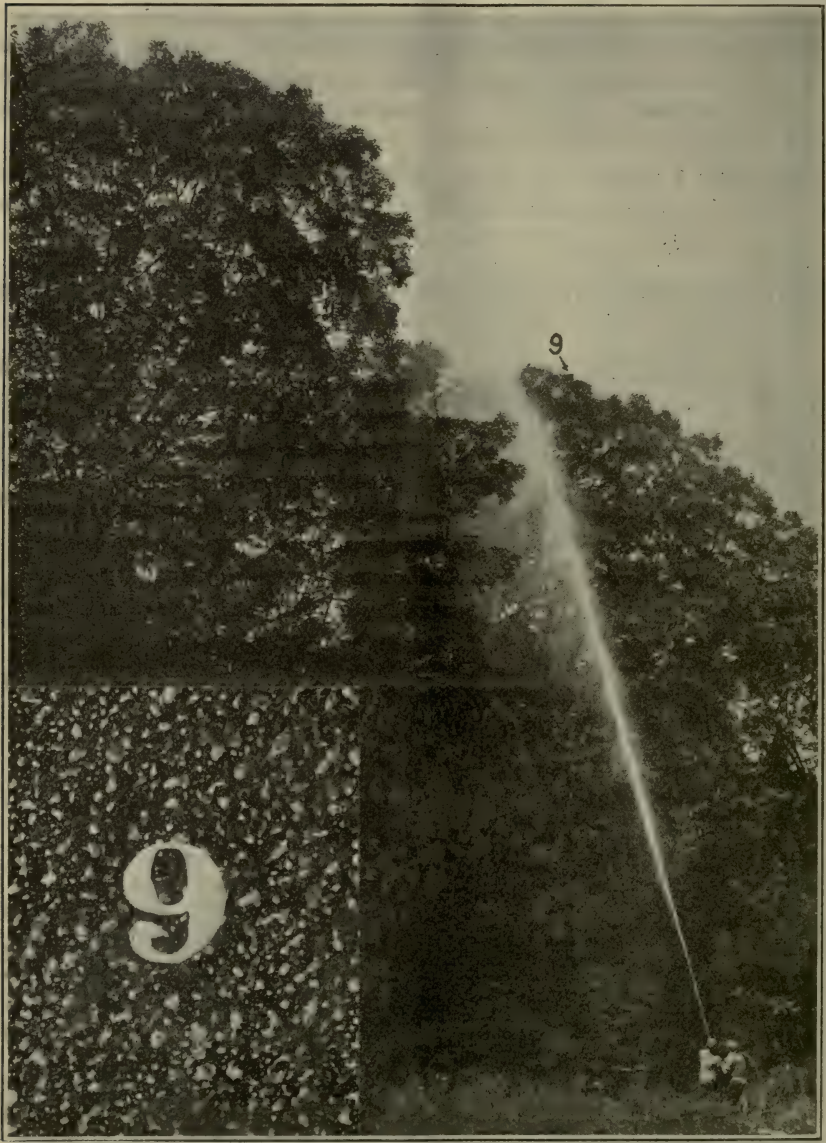

FIG. 11.—Spraying trees 85 feet high with high-power sprayer. Note thorough distribution of poison on plate (*9*) located at top of tree. (Worthley.)

material referred to on pages 16 and 17. Orchard infestations can be managed by following up these methods, and it will not require much additional expense or a great deal of extra work to protect the trees. In making this statement it is assumed that the orchard is being cared for by up-to-date methods for protection from the codling moth and other injurious insects and diseases, and it is improbable that these results can be brought about in neglected orchards or where the owners do not practice the best horticultural methods in handling their growing trees.

HAND METHODS FOR CONTROLLING THE GIPSY MOTH IN CITIES AND TOWNS.

The same methods that are used in orchards are applicable in cities and towns and for the treatment of park and shade trees. In certain instances it probably would be advisable to use bands and to discontinue spraying, especially in cases where the infestation is light or moderate. If the infestation is bad, creosoting, banding, and spraying all should be used in their season, in order that the insect may be brought under control and the numbers present reduced to a minimum.

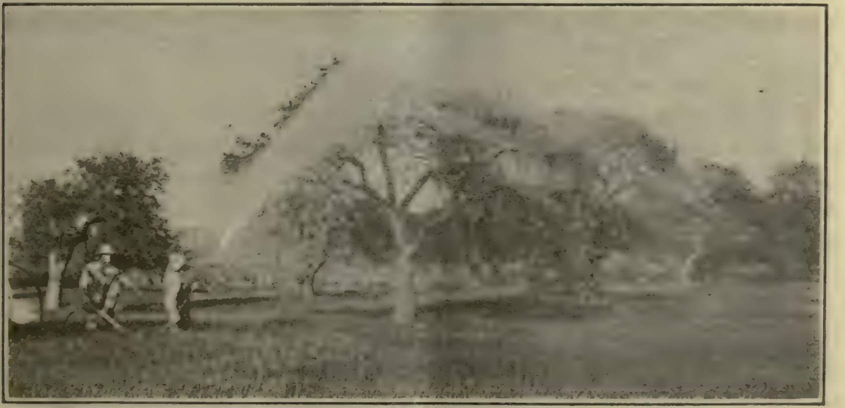

FIG. 12.—Spraying orchard with solid stream, using spreader. (Worthley.)

The proper method of handling the gipsy moth in any town, city or park, or on private estates, should be based on the infestation as determined by some one who is familiar with gipsy-moth work, if the best results are to be secured at a minimum expense. Much energy and money may be wasted in applying remedies unless their application is based on a thorough knowledge of existing conditions. An owner of an infested estate should have an examination made by some qualified person who can give reliable recommendations as to treatment. It should be borne in mind that conditions as to infestation vary from year to year, and this should be considered when plans for treatment are being made.

METHODS OF CONTROLLING THE GIPSY MOTH IN WOODLAND.

Satisfactory control of the gipsy moth in woodland by the employment of hand methods such as already have been mentioned is entirely impracticable unless the tree growth is particularly valued for purposes other than lumber. If the woodland is situated near a large city and occupies space that is likely to be utilized in a few years for building lots, considerable money may be expended to advantage in protecting the trees, as these will make the property much more valuable when the land is subdivided. Limited areas of woodland on private estates may be of sufficient value to the owners to justify a considerable expenditure for moth destruction. In all cases, however, the species of trees involved should be studied carefully before a plan of work is adopted in order that the expense may be reduced as much as possible. Unfortunately the difficulty of treating the woodlands in the infested area of New England is considerably increased by the fact that they are for the most part composed of a variety of species in mixture.

Experiments have shown that coniferous trees are not injured by the gipsy moth if grown in isolated pure stands, and if the growth is such that the trees can be thinned to a stand of conifers no hand suppressive measures are necessary in order to prevent injury by this insect. (See fig. 13.) Such lots will also be immune from attack by the brown-tail moth, as the larvæ of this insect do not feed on conifers.

If mixtures containing a large percentage of deciduous trees are to be protected from moth injury, it is very necessary that the species involved should be considered carefully before a decision is reached as to the best methods of treatment. Sometimes practical methods of thinning can be adopted so that tree species will be left that are only slightly subject to injury by these insects. A limited number of experiments have shown that mixtures of chestnut, pine, red maple, ash, and hickory, regardless of the proportion of each species, are seldom injured by the gipsy moth.

In woodlands the oaks are the most favored food plant of this insect, and unfortunately the infested region abounds in large areas where these species predominate. At present there seems to be no means aside from hand treatment which will prevent serious injury to oak woodland, but as a large part of such land consists of poor sprout growth the amount of damage sustained is not always so great as it might at first appear. The greatest injury likely to be caused in such areas where oaks and gray birch abound is the dying of small seedlings of pine or other valuable species which have been denuded by the caterpillars after the oaks and birches have been defoliated. This leaves the prospective woodland in a much worse condition than it was before the defoliation took place and reduce greatly the chance that the sprout growth will be replaced by any species of value that can withstand gipsy-moth attack. This problem is being specially studied and considered in the hope that some economical method may be devised for protecting and improving

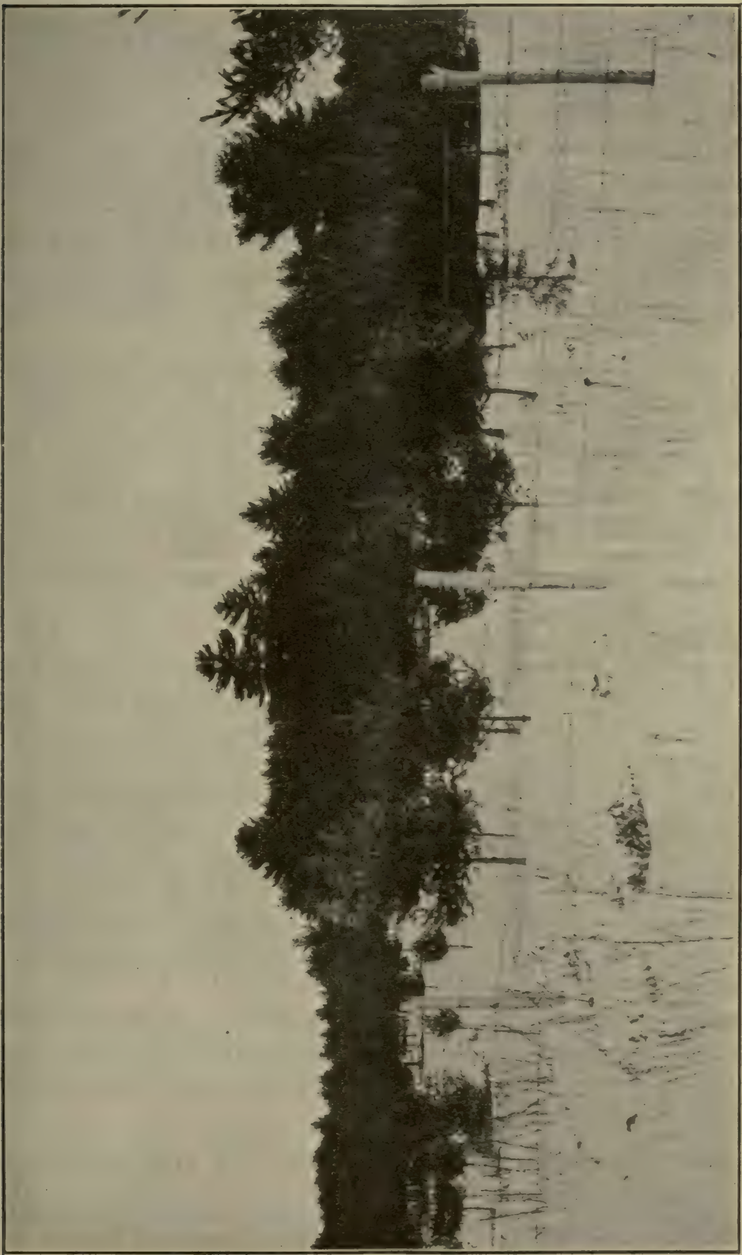

FIG. 13.—Solid white-pine block near Nashua, N. H.: Small trees in foreground were transplanted some years ago. The foliage of this species is not attacked by *small* gipsy-moth larvæ, so it is not injured if grown in clean stands.

woodlots of this character at moderate expense. It is true that in considerable areas of oak woodland the trees, although not mature, could be utilized for small timber, railroad ties, or cordwood, and in cases of bad infestation such woodland should be cut promptly if the wood can be sold to advantage. On cheap cut-over or infested lands in many sections of the territory planting of white pine might be done to advantage, but as this involves considerable expense and as the future crop can not be harvested for a period of years, the question as to the desirability of managing any woodlot in this way must in the end be decided by the owner of the property.

The presence of the chestnut-bark disease or the white-pine blister rust in a locality should receive due consideration before plans are made for planting or encouraging the growth of either of these species.

If the practice common in some European countries of maintaining municipal or State forests were well developed in the New England States, it would be possible in a period of years to transform considerable areas of land which are now destined to be worthless, and which form a favorable feeding ground for the gipsy moth, into well-managed forests of valuable growth.

METHODS OF CONTROLLING THE BROWN-TAIL MOTH IN WOODLAND.

The damage caused by the brown-tail moth ordinarily is not so severe as is that resulting from gipsy-moth infestation because the former species does not have so wide a range of food plants and, further, because the bulk of the feeding is done early in the season so that the trees have an opportunity to recover before midsummer. In the territory where both insects exist the caterpillars of the gipsy moth supplement the work which is done by those of the brown-tail moth and the injury, therefore, is increased greatly. The large areas of oak-sprout growth furnish abundant food for brown-tail moth caterpillars, and as a result enormous numbers of the moths develop which migrate each season to the cities and towns and render it necessary for hand suppressive measures to be put in force each year. The area reinfested in this way depends largely on the prevailing winds during the month of July when the moths are flying. Elimination of oak, scrub apple, and wild-cherry trees would assist greatly in reducing the numbers of this pest.

STATE WORK AGAINST THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

Each of the New England States is carrying on work for the control of these insects. The organization varies because of local conditions, but the same general methods of field work are employed.

In Maine the work is in charge of the commissioner of agriculture, who has authority to appoint a superintendent of moth work. The southwestern portion of the State is from generally to badly infested with the gipsy moth, while in the outlying area only scattering infestations have been found. The brown-tail moth usually is most abundant along the coast or near the main water courses. Seven thousand six hundred and fourteen square miles in this State are infested with the gipsy moth and 16,783 square miles with the brown-tail moth.

In New Hampshire the moth work is in charge of the State entomologist. Five thousand nine hundred and twenty square miles are infested with the gipsy moth and 8,113 square miles with the brown-tail moth. The heaviest gipsy-moth infestations in the State are south of Lake Winnepesaukee, although extensive infested areas occur west of the Merrimac River.

In Vermont the moth work is in charge of the commissioner of agriculture, who appoints a deputy to carry on the field work. Only one town in this State has a gipsy-moth infestation and this consists of a few eggs clusters which have been treated and the locality cared for by employees of the Bureau of Entomology. The whole area known to be infested by the brown-tail moth amounts to 2,666 square miles, but the infestation is very light and in many of the towns within this area it is very difficult to find this insect.

The State forester has charge of the moth work in Massachusetts. Each infested town is required by law to select a local superintendent, whose appointment must be approved by the State forester. Owners are required by law to keep their property free from these pests, but can not be compelled to expend for this purpose more than $5 on each $1,000 assessed valuation. Town and city appropriations are made to give proper treatment to the street trees and those in public parks, and if sufficient funds are not available to do the work properly, financial aid is given by the State. The gipsy moth infested area in Massachusetts covers 4,980 square miles and 6,115 square miles are infested to a greater or less extent by the brown-tail moth.

The moth work in Rhode Island is in charge of the State board of agriculture and is placed by it under the supervision of the State entomologist. Every town in the State is infested with both of these pests. The insects are most abundant in the northern part of the State and in the territory immediately surrounding Providence.

In Connecticut the work is in charge of the State entomologist. The brown-tail moth infestation covers 1,993 square miles and the gipsy-moth infestation 639 square miles. There is great danger that the gipsy moth will spread rapidly in this State, owing to the fact that the oak, which is a food plant favored by this insect, is one of the predominating trees.

The small colony of the gipsy moth which was found in Geneva, N. Y., in 1912 has been exterminated. Effective work was done by the State department of agriculture, and several inspections of the colony and its surroundings have been made by employees of the Bureau of Entomology. The colony located at Mount Kisco, Westchester County, N. Y., in May, 1914, has been treated thoroughly and no egg clusters have been found during the past year. Persistent work has been done in an attempt to stamp out this colony, both by the State and by the Bureau of Entomology, and it is hoped that this may be accomplished after another season's work.

In February, 1914, a colony was reported on an estate at Bratenahl, near Cleveland, Ohio. The territory was scouted thoroughly by employees of the Bureau of Entomology and treatment applied by the State nursery inspector. No infestation has been found in the colony or its surroundings for more than a year, and it is believed that the insect is exterminated.

A small colony was found at Rutherford, N. J., in July, 1914. It has received careful attention and as a result of the work done has been exterminated.

WORK CARRIED ON BY THE BUREAU OF ENTOMOLOGY.

The work carried on by the Bureau of Entomology of the United States Department of Agriculture is designed to prevent the spread of these insects.

Owing to the freedom with which the female brown-tail moth flies it is difficult by hand measures to prevent the spread of this species, as a heavy migration may take place into new territory during any year when the wind is favorable at the time the moths are flying.

The spread of the gipsy moth has been much slower. All the principal infestations found in new territory have been along the line of the winds prevailing when the gipsy-moth caterpillars are hatching in the spring. The greatest danger of spread is toward the north and northeast, as the warm winds in the spring, particularly along the coast, are from the south and southwest. In New Hampshire, between the Merrimac and Connecticut Rivers, and in the infested region south of it, extending through Massachusetts, Rhode Island, and Connecticut to Long Island Sound, the problem of wind spread has the greatest bearing on the further dispersion of the gipsy moth. Scouting and extermination work is carried on extensively in this region under the direction of Mr. L. H. Worthley and every effort is being made not only to determine whether infestations exist in the new territory, but to exterminate the insects in several tiers of towns adjoining the border in order that wind spread into the territory that already has been treated may be prevented.

In town or city work the bureau advises that careful attention be given to woodland infestation or isolated trees, particularly if they are located on high elevations immediately outside the residential area, as such colonies may furnish a supply of caterpillars which will be distributed throughout the town after it has been cleaned.

Under present conditions, owing to the decrease in the severity of gipsy-moth infestation in most sections, spraying becomes an economical means of treatment and in some cases is used exclusively for control.

A great amount of experimental work has been conducted in order that better methods of controlling these insects may be determined. The introduction of natural enemies from Europe and Japan has proceeded systematically and good results are being noted in many localities. A systematic study of the wilt disease, which attacks gipsy-moth caterpillars in the field, is being made in cooperation with the Bussey Institution of Harvard University. Silvicultural investigations, which have for their purpose the adoption of better methods of forest management which will assist in the control of these pests, are being carried on in cooperation with the Forest Service of this department. This work is conducted by Mr. George E. Clement.

The entire infested area—20,211 square miles occupied by the gipsy moth and 36,684 square miles occupied by the brown-tail moth—has been placed under quarantine by the Federal Horticultural Board, and shipments of nursery stock, lumber, cordwood, and other forest products and stone and quarry products are not permitted to leave the territory unless they have been inspected and are accompanied by a certificate stating that they are free from infestation. This work is designed to prevent the spread of the insects for long distances and is being administered by Mr. D. M. Rogers.

COOPERATIVE WORK.

Since the gipsy moth and brown-tail moth work was started by the Bureau of Entomology more or less cooperative work has been carried on with the States concerned. The introduction of parasites and natural enemies of the gipsy moth was conducted cooperatively with the State of Massachusetts for several years. After the infestation covered large areas in other States an arrangement was made for this work to be carried on by the Bureau of Entomology. The general plan of field work is for the bureau to handle the territory embracing several tiers of towns along the outside border of gipsy-moth infestation, while the States manage the work inside this area. The quarantine covers the entire infested area, while the experimental work, including the colonization of parasites, is being carried out in a systematic way for the purpose of developing better methods for the use of all concerned and to bring about the dispersion of the various parasites over the entire infested area as rapidly as possible.

THE OUTLOOK.

Infestation by the brown-tail moth is less severe than it has been for a number of years. A marked reduction in the number of winter webs has been noted, and if natural enemies continue as effective as they are at present, this insect can be controlled with small expense. At the present time, however, there is no way of telling exactly what will happen in this respect, and a careful record is being kept as to the abundance of this insect so that more work can be done upon it if the effectiveness of natural enemies should be suddenly reduced.

The gipsy-moth infestations have been reduced considerably during the last few years. The territory infested has remained practically the same and the improved methods which have been employed have shown good results. The great danger that widespread infestation will be brought about by wind drift of the small caterpillars can not be ignored and every effort is being made to restrict this danger as much as possible. When parasites are becoming more effective, and the increase of the gipsy moth in the field is slow, is the proper time to exert every effort to reduce further the abundance of the insect and so far as possible decrease the area infested.

THE HOUSE FLY

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Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

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Show this bulletin to a neighbor. Additional copies may be obtained free from the Division of Publications, United States Department of Agriculture

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THE PRESENCE of flies is an indication of uncleanliness, insanitary conditions, and improper disposal of substances in which they breed. They are not only annoying; they are actually dangerous to health, because they may carry disease germs to exposed foods.

It is therefore important to know where and how they breed, and to apply such knowledge in combating them. This bulletin gives information on this subject. Besides giving directions for ridding the house of flies by the use of screens, fly papers, poisons, and flytraps, it lays especial emphasis on the explanation of methods of eliminating breeding places and preventing the breeding of flies.

THE HOUSE FLY.[1]

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KINDS OF FLIES FOUND IN HOUSES.

SEVERAL species of flies are found commonly in houses. Some of them so closely resemble the true house fly that it requires very careful observation to distinguish them from it.

One of these is the biting stable fly (fig. 1). It occurs frequently in houses and differs from the house fly in the important particular that its mouth parts are formed for piercing the skin. This fly is so often mistaken for the house fly that most people think that the house fly can bite.

Another frequent visitant of houses, particularly in the spring and fall, is the cluster fly.[2] It is somewhat larger than the house fly, and is distinguished by its covering of fine yellowish hairs. Occasionally this fly occurs in houses in such numbers as to cause great annoyance. It gets its name of "cluster fly" from its habit of collecting in compact groups or clusters in protected corners during cold periods. In the maggot stage it is parasitic on certain angleworms, especially a common greenish colored earthworm.

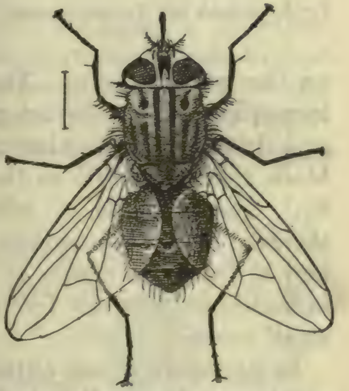

FIG. 1.—The stable fly or biting house fly (*Stomoxys calcitrans*). Much enlarged.

Another species, which almost exactly resembles the house fly, is the stable fly shown in figure 2. It does not bite as does the biting stable fly. It breeds in decaying vegetable matter and in excrement.

Several species of metallic greenish or bluish flies also are found occasionally in houses. These include the blowfly or meat fly,[3] the blue-bottle (fig. 3) and the green-bottle (fig. 4) flies. They breed in decaying animal matter.

There is still another species, smaller than any of those so far mentioned, which is sometimes called the "lesser house fly."[4] A related species is shown in figure 5. The "lesser house fly" is distinguished from the ordinary house fly by its paler and more pointed body. The male, which is commoner than the female, has large pale patches at the base of the abdomen, which are translucent when the fly is seen on the window pane. These little flies are not the young of the larger flies. Flies do not grow after the wings have once expanded and dried. Still another fly, and this one is still smaller, is a jet black species known as the window fly.[1] Its larva is a white, very slender, almost threadlike creature and is found in cracks of the floor in buildings, where it feeds on other small insects.

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[1] *Musca domestica* L. [2] *Pollenia rudis* Fab. [3] *Calliphora erythrocephala* Meig. [4] *Fannia canicularis* L.

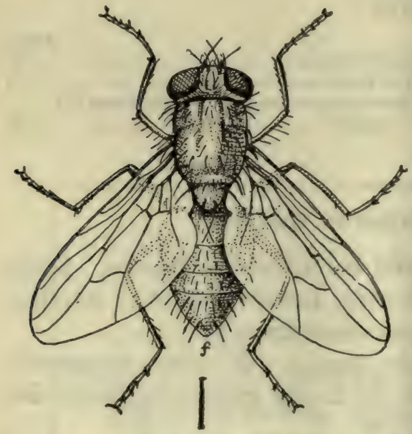

FIG. 2.—A stable fly (*Muscina stabulans*). Much enlarged.

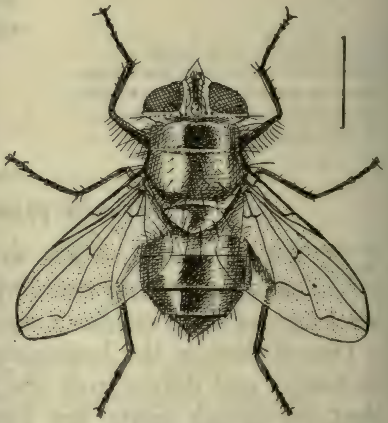

FIG. 3.—One of the blue-bottle flies (*Phormia terraenovae*). Much enlarged.

In late summer and autumn many specimens of a small fruit fly, known as the "vinegar fly" (fig. 6), make their appearance, attracted by the odor of overripe fruit.

All of these species, however, are greatly dwarfed in numbers by the common house fly. In 1900 the senior author made collections of the flies in dining rooms in different parts of the country, and found that the true house fly made up 98.8 per cent of the whole number captured. The remainder comprised various species, including those mentioned above.

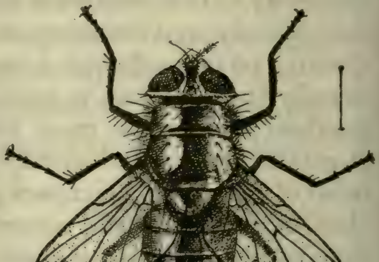

FIG. 4. One of the green-bottle flies (*Lucilia caesar*). Much enlarged.

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[1] *Scenopinus fenestralis* L.

WHERE THE TRUE HOUSE FLY LAYS ITS EGGS.

The true house fly (fig. 7), which is found in nearly all parts of the world, is a medium-sized fly with four black stripes on the back and a sharp elbow in one of the veins of the wings. The house fly can not bite, its mouth parts being spread out at the tip for sucking up liquid substances.

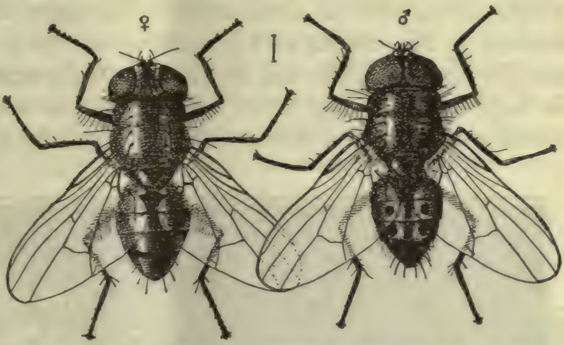

Fig. 5.—A "little house fly" (*Fannia brevis*): Female at left, male at right. Much enlarged.

The eggs (figs. 8, 9) are laid upon horse manure. This substance seems to be its favorite larval food. It will breed also in human excrement, and because of this habit it is very dangerous to the health of human beings, carrying as it does the germs of intestinal diseases, such as typhoid fever and cholera, from the excreta to food supplies. It has also been found to breed freely in hog manure and to some extent in cow and chicken manure. Indeed, it will lay its eggs on a great variety of decaying vegetable and animal materials, but of the flies that infest dwelling houses, both in cities and on farms, a vast proportion come from horse manure.

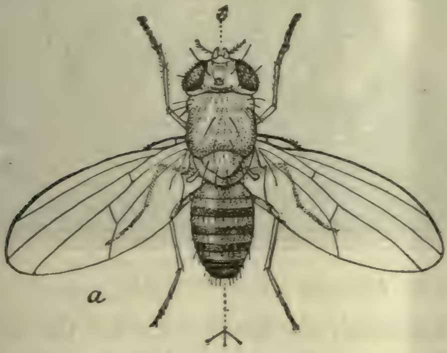

Fig. 6.—The vinegar fly (*Drosophila ampelophila*). Much enlarged.

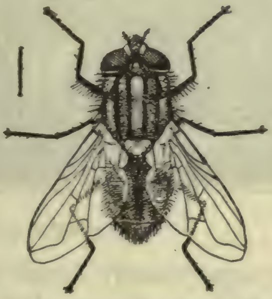

Fig. 7.—The true house fly (*Musca domestica*). Enlarged.

It often happens, however, that this fly is very abundant in localities where little or no horse manure is found, and in such cases it breeds in other manure or in slops or fermenting vegetable material, such as spent hops, moist bran, ensilage, or rotting potatoes. Accumulations of organic material on the dumping grounds of towns and cities often produce flies in great numbers.

The number of eggs laid by an individual fly at one time undoubtedly is large, probably averaging about 120, and as a single female will lay at least two and possibly four such batches, the enormous numbers in which the insects occur are thus plainly accounted for, especially when the abundance and universal occurrence of appropriate larval food is considered. The eggs are deposited below the surface in the cracks and interstices of the manure, several females usually depositing in one spot, so that the eggs commonly are found in large clusters (fig. 8) in selected places near the top of the pile, where a high degree of heat is maintained by the fermentation below.

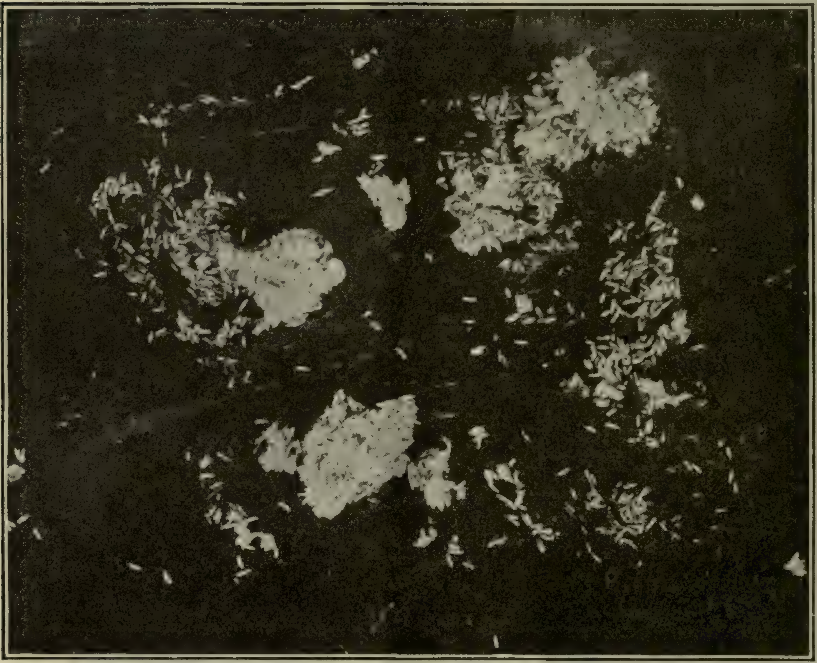

FIG. 8.—Eggs of the house fly. About natural size. (Newstead.)

The eggs usually hatch in less than 24 hours. Under the most favorable conditions of temperature and moisture the egg state may last hardly more than eight hours. The maggots which issue from the eggs are very small and transparent. They grow rapidly, completing the growth of the larva stage in four or five days. The larva period may be prolonged greatly by low temperature or by dryness or scarcity of the larval food. As the larvæ (fig. 10) attain full size they gradually assume a creamy white color. Just before pupation they become very restless and migrate from their feeding ground in search of a favorable place in which to pass the pupa stage. They will often congregate at the edges of manure piles near the ground or burrow into the soil beneath, or they may crawl considerable distances away from the pile to pupate in the ground or in loose material under the edges of stones, boards, etc.

The pupæ (fig. 11), or "sleepers," are more or less barrel shaped and dark brown in color. In midsummer this stage lasts from three to ten days, four to five days being the usual duration. The pupa stage is easily affected by temperature changes and may be prolonged during hibernation for as long as four or five months. Numerous rearing experiments in various parts of the country have shown that the shortest time between the deposition of eggs and the emergence of the adult fly is eight days, and 10 and 12 day records were very common.

The adult fly, upon emerging from the puparium, works its way upward through the soil or manure and upon reaching the air it crawls about while its wings expand and the body hardens and assumes its normal coloration. In a very few days the female is ready to deposit eggs. In recent experiments it was found that the time between the emergence of the adults and the first deposition of eggs is considerably shorter than previously was thought to be the case. Only three or four days are necessary in midsummer for the female to reach sexual maturity. As in the case of other periods of its life history, so the preoviposition period is prolonged considerably by the lower temperatures of spring and autumn. In midsummer, with a developmental period of from 8 to 10 days from egg to adult, and a preoviposition period of from 3 to 4 days, a new generation would be started every 11 to 14 days. Thus the climate of the District of Columbia allows abundance of time for the development of 10 to 12 generations every summer.

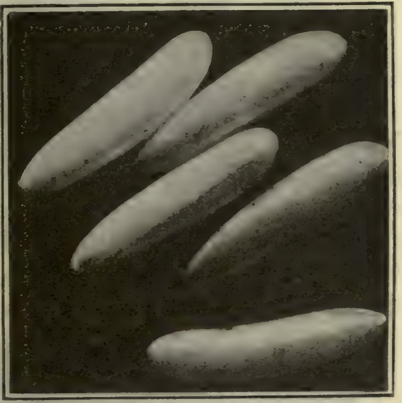

FIG. 9.—Eggs of the house fly. Highly magnified. (Newstead.)

HOW THE HOUSE FLY PASSES THE WINTER.

The prevailing opinion that the house fly lives through the winter as an adult, hiding in cracks and crevices of buildings, etc., appears to be erroneous. Under outdoor conditions house flies are killed during the first really cold nights; that is, when the temperature falls to about 15° or 10° F. In rooms and similar places protected from winds and partially heated during the winter flies have been kept alive in cages for long periods; but they never lived through the entire winter. In several cases longevity records of from 52 to 54 days were obtained. In other experiments one record of 70 days and another of 91 days was obtained. The average temperature of these experiments varied from 44° to 57° F. The conditions of these experiments seemed to have been most favorable, but flies normally do not seek such places. No uncaged house flies were found during three seasons' observations in unheated and only partially heated attics, stables, unused rooms, etc., where favorable temperature conditions prevailed. The common occurrence in such places of the cluster fly and a few other species, which may be easily mistaken for the house fly, is responsible for the prevailing belief as to the way the house fly overwinters. There is therefore no reliable evidence whatever that adult house flies emerging during October and November pass the winter and are able to deposit their eggs the following spring, although they may continue active in heated buildings until nearly the end of January. On the other hand, there is evidence that house flies pass the winter as larvæ and pupæ, and that they sometimes breed continuously throughout the winter. In experiments at both Dallas, Tex., and Bethesda, Md., house flies have been found emerging during April from heavily infested manure heaps which had been set out and covered with cages during the preceding autumn, this proving that it is possible for them to overwinter as larvæ and pupæ in manure heaps or in the soil beneath such heaps.

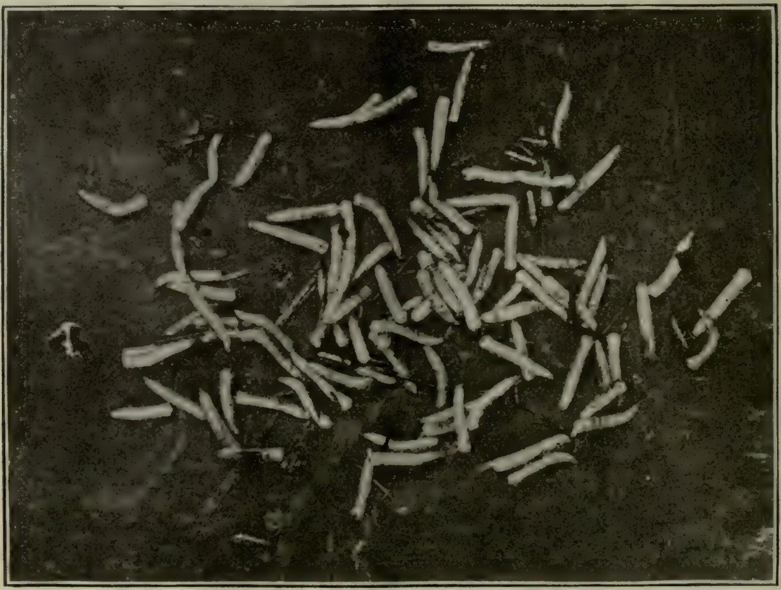

FIG. 10.—Larvæ, or maggots, of the house fly. About natural size. (Newstead.)

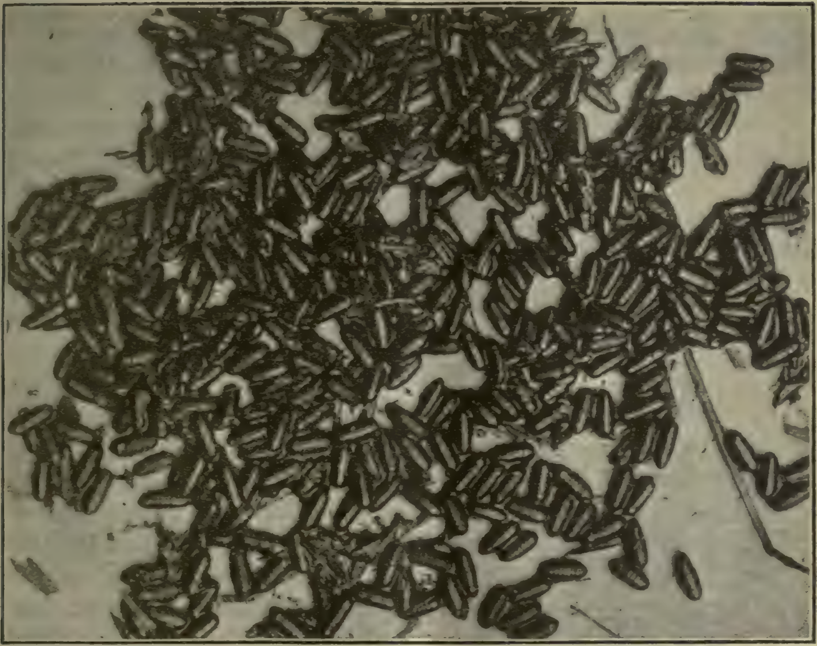

FIG. 11.—Pupæ of the house fly. About natural size. (Newstead.)

The second way in which the house fly may pass the winter is by continuous breeding. As is well known, house flies congregate in heated rooms with the approach of the winter season. If no food or breeding materials are present they eventually will die. Where they have complete access to food they may persist as late as the end of January. However, where they have access to both food and suitable substances for egg laying they will continue breeding just as they do outdoors during the summer. Rearing experiments have been conducted in a bakery, in greenhouses, and in animal breeding houses during winter seasons. Even in very cold climates there are undoubtedly many places, especially in cities, where house flies would have opportunity to pass the winter in this manner.

CARRIAGE OF DISEASE BY THE HOUSE FLY.

The body of the house fly is covered thickly with hairs and bristles of varying lengths, and this is especially true of the legs. Thus, when it crawls over infected material it readily becomes loaded with germs, and subsequent visits to human foods result in their contamination. Even more dangerous than the transference of germs on the legs and body of the fly is the fact that bacteria are found in greater numbers and live longer in the alimentary canal. These germs are voided, not only in the excrement of the fly, but also in small droplets of regurgitated matter which have been called "vomit spots." When we realize that flies frequent and feed upon the most filthy substances (it may be the excreta of typhoid or dysentery patients or the discharges of one suffering from tuberculosis), and that subsequently they may contaminate human foods with their feet or excreta or vomit spots, the necessity and importance of house-fly control is clear.

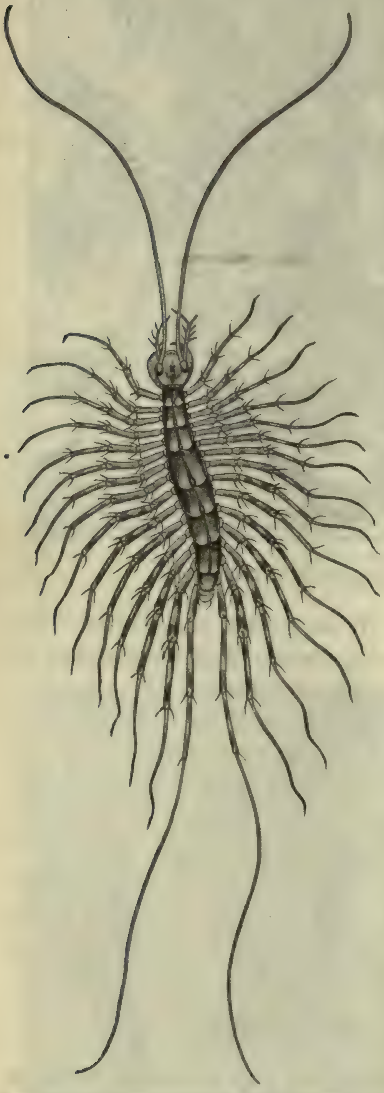
FIG. 12.—The house centipede (*Scutigera forceps*): Adult. Natural size. (Marlatt.)

In army camps, in mining camps, and in great public works, where large numbers of men are brought together for a longer or shorter time, there is seldom the proper care of excreta, and the carriage of typhoid germs from the latrines and privies to food by flies is common and often results in epidemics of typhoid fever.

And such carriage of typhoid is by no means confined to great temporary camps. In farmhouses in small communities, and even in badly cared for portions of large cities, typhoid germs are carried from excrement to food by flies, and the proper supervision and treatment of the breeding places of the house fly become most important elements in the prevention of typhoid.

In the same way other intestinal germ diseases, such as Asiatic cholera, dysentery, and infantile diarrhea, are all so carried. There is strong circumstantial evidence also that tuberculosis, anthrax, yaws, ophthalmia, smallpox, tropical sore, and the eggs of parasitic worms may be and are carried in this way. Actual laboratory proof exists in the case of a number of these diseases, and where lacking is replaced by circumstantial evidence amounting almost to certainty.

NATURAL ENEMIES OF THE HOUSE FLY.

The house fly has a number of natural enemies. The common house centipede (fig. 12) destroys it in considerable numbers; there is a small reddish mite which frequently covers its body and gradually destroys it; it is subject to the attacks of four-winged wasplike parasites in its larva and pupa condition; and it is destroyed by predatory beetles and ants at the same time.

The most effective enemy of the house fly, however, is a fungous disease,[1] which carries off flies in large numbers, particularly toward the close of the season.

CONTROL MEASURES.

THE USE OF SCREENS.

A careful screening of windows and doors during the summer months, with the supplementary use of sticky fly papers, is a protective measure against house flies known to everyone. As regards screening it is only necessary here to emphasize the importance of keeping food supplies screened or otherwise covered so that flies can gain no access to them. This applies not only to homes, but also to stores, restaurants, milk shops, and the like. Screening, of course, will have no effect in decreasing the number of flies, but at least it has the virtue of lessening the danger of contamination of food.

FLY PAPERS AND POISONS.

The use of sticky fly papers to destroy flies that have gained access to houses is well known. Fly-poison preparations also are common. Many of the commercial fly poisons contain arsenic, and their use in the household is attended with considerable danger, especially to children. This danger is lessened by the use of a weak solution of formalin. A very effective fly poison is made by adding 3 teaspoonfuls of the commercial formalin to a pint of milk or water sweetened with a little brown sugar.

The United States Public Health Service recommends a 1 per cent solution of sodium salicylate as almost equally effective. This is prepared by dissolving 3 teaspoonfuls of the pure chemical (a powder) in a pint of water, some brown sugar being added to render it more attractive to flies. A convenient way of exposing these poisons is by partly filling an ordinary drinking glass with the solution. A saucer or plate is then lined with white blotting paper cut the size of the dish and placed bottom up over the glass. The whole is then quickly inverted and a small match stick placed under the edge of the glass. As the solution evaporates from the paper more flows out from the glass and thus the supply is automatically renewed.

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[1] *Empusa muscae.*

FLYTRAPS.

Flytraps may be used to advantage in decreasing the number of flies. Their use has been advocated not only because of the immediate results, but because of the chances that the flies may be caught before they lay their first batch of eggs, and that thus the possible number of future generations will be reduced greatly.

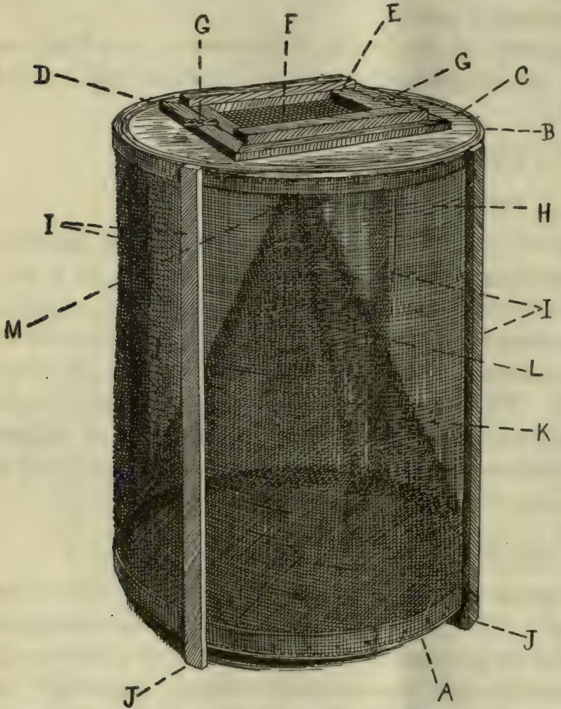

FIG. 13.—Conical hoop flytrap; side view. *A*, Hoops forming frame at bottom. *B*, Hoops forming frame at top. *C*, Top of trap made of barrel head. *D*, Strips around door. *E*, Door frame. *F*, Screen on door. *G*, Buttons holding door. *H*, Screen on outside of trap. *I*, Strips on side of trap between hoops. *J*, Tips of these strips projecting to form legs. *K*, Cone. *L*, United edges of screen forming cone. *M*, Aperture at apex of cone. (Bishopp.)

Many types of flytraps are on the market, and as a rule the larger ones are the more effective. Anyone with a few tools, however, can construct flytraps for a small part of the price of the ready-made ones. A trap which is very effective in catching flies and is easily made, durable, and cheap, may be made as follows:

"The trap (fig. 13) consists essentially of a screen cylinder with a frame made of barrel hoops, in the bottom of which is inserted a screen cone. The height of the cylinder is 24 inches, the diameter 18 inches, and the cone is 22 inches high, and 18 inches in diameter at the base. Material necessary for this trap consists of four new or secondhand wooden barrel hoops, one barrel head, four laths, 10 feet of strips 1 to 1½ inches wide by one-half inch thick (portions of old boxes will suffice), 61 linear inches of 12 or 14 mesh galvanized screening 24 inches wide for the sides of the trap and 41 inches of screening 26 inches wide for the cone and door, an ounce of carpet tacks, and two turn buttons, which may be made of wood." The cost of the material for this trap is not great, and in many cases the barrel hoops, barrel head, lath, and strips can be obtained without expense.

"In constructing the trap two of the hoops are bent in a circle (18 inches in diameter on the inside), and nailed together, the ends being trimmed to give a close fit. These form the bottom of the frame (*A*), and the other two, prepared in a similar way, the top (*B*). The top (*C*) of the trap is made of an ordinary barrel head with the bevel edge sawed off sufficiently to cause the head to fit closely in the hoops and allow secure nailing. A square, 10 inches on the side, is cut out of the center of the top to form a door. The portions of the top (barrel head) are held together by inch strips (*D*) placed around the opening one-half inch from the edge to form a jamb for the door. The door consists of a narrow frame (*E*) covered with screen (*F*) well fitted to the trap and held in place (not hinged) by buttons (*G*). The top is then nailed in the upper hoops and the sides (*H*) formed by closely tacking screen wire on the outside of the hoops. Four laths (*I*) (or light strips) are nailed to the hoops on the outside of the trap to act as supports between the hoops, and the ends are allowed to project 1 inch at the bottom to form legs (*J*). The cone (*K*) is cut from the screen and either sewed with fine wire or soldered where the edges meet at *L*. The apex of the cone is then cut off to give an aperture (*M*) 1 inch in diameter. It is then inserted in the trap and closely tacked to the hoop around the base."[1]

The effectiveness of the traps will depend on the selection of a good bait. For attracting house flies beer is probably the best. It loses much of its attractiveness after the first stages of fermentation are over, and for this reason it should be renewed every day or two. Milk is also a good bait. Overripe or fermenting bananas crushed and placed in the bait pans give good results. A combination of bananas and milk is more attractive than either used separately. A mixture of 3 parts water and 1 part cheap molasses is very attractive after it has been allowed to ferment for a day or two. A mixture of equal parts brown sugar and cheese (or curd of sour milk), thoroughly moistened, gives good results after it has been allowed to stand for three or four days. For catching blowflies and other meat-infesting flies the best bait is the mucous membrane from the lining of the intestines of hogs. Ordinary fish or meat scraps may be used.

PREVENTIVE MEASURES.

Fly papers, poisons, and traps are at best only temporary expedients. The most logical method of abating the fly nuisance is the elimination or treatment of all breeding places. It would appear from what is known of the life history and habits of the common house fly that it is perfectly feasible for cities and towns to reduce the numbers of these annoying and dangerous insects so greatly as to render them of comparatively slight account.

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[1] Bishopp, F. C. Flytraps and their operation. U. S. Dept. Agr. Farmers' Bul. 734, p. 3–5. 1916.

CONSTRUCTION AND CARE OF STABLES.

In formulating rules for the construction and care of stables and the disposal of manure the following points must be taken into consideration. In the first place, the ground of soil-floor stables may offer a suitable place for the development of fly larvæ. The larvæ will migrate from the manure to the soil and continue their growth in the moist ground. This takes place to some extent even when the manure is removed from the stables every day. Even wooden floors are not entirely satisfactory unless they are perfectly water-tight, since larvæ will crawl through the cracks and continue their development in the moist ground below. Water-tight floors of concrete or masonry, therefore, are desirable. Flies have been found to breed in surprising numbers in small accumulations of material in the corners of feed troughs and mangers, and it is important that such places be kept clean.

FLY-TIGHT MANURE PITS OR BINS.

The Bureau of Entomology for some years has advised that manure from horse stables be kept in fly-tight pits or bins. Such pits can be built in or attached to the stable so that manure can be easily thrown in at the time of cleaning and so constructed that the manure can be readily removed. The essential point is that flies be prevented from reaching the manure, and for this reason the pit or bin must be tightly constructed and the lid kept closed except when the manure is being thrown in or removed. The difficulty has been that manure often becomes infested before it is put into the container, and flies frequently breed out before it is emptied and often escape through the cracks. To obviate these difficulties a manure box or pit with a modified tent trap or cone trap attached is desirable.

In order to retain the fertilizing value of manure to the greatest extent it is advisable that air be excluded from it as much as possible and that it be protected from the leaching action of rains. This being the case, there is really no necessity for covering a large portion of the top of the box with a trap, but merely to have holes large enough to attract flies to the light, and to cover these holes with ordinary conical traps, with the legs cut off, so that the bottoms of the traps will fit closely to the box. The same arrangement can be made where manure is kept in a pit.

FREQUENCY WITH WHICH MANURE SHOULD BE REMOVED.

Another point must be considered in deciding the question as to how often the manure should be removed. In this connection it should be borne in mind that when the larvæ have finished feeding they will often leave the manure and pupate in the ground below or crawl some distance away to pupate in débris under boards or stones and the like. Hence the manure should be removed before the larvæ reach the migratory stage; that is to say, removal is necessary every three days, and certainly not less frequently than twice a week during the summer months. A series of orders issued in 1906 by the health department of the District of Columbia, on the authority of the Commissioners of the District, covers most of these points, and these orders, which may well serve as a model to other communities desiring to undertake similar measures, may be briefly condensed as follows:

HEALTH OFFICE REGULATIONS FOR CONTROL OF HOUSE FLIES IN CITIES.

All stalls in which animals are kept shall have the surface of the ground covered with a water-tight floor. Every person occupying a building where domestic animals are kept shall maintain in connection therewith a bin or pit for the reception of manure and, pending the removal from the premises of the manure from the animal or animals, shall place such manure in said bin or pit. This bin shall be so constructed as to exclude rain water and shall in all other respects be water-tight, except as it may be connected with the public sewer. It shall be provided with a suitable cover and constructed so as to prevent the ingress and egress of flies. No person owning a stable shall keep any manure or permit any manure to be kept in or upon any portion of the premises other than the bin or pit described, nor shall he allow any such bin or pit to be overfilled or needlessly uncovered. Horse manure may be kept tightly rammed into well-covered barrels for the purpose of removal in such barrels. Every person keeping manure in the more densely populated parts of the District shall cause all such manure to be removed from the premises at least twice every week between June 1 and October 31, and at least once every week between November 1 and May 31 of the following year. No person shall remove or transport any manure over any public highway in any of the more densely populated parts of the District except in a tight vehicle, which, if not inclosed, must be effectually covered with canvas, so as to prevent the manure from being dropped. No person shall deposit manure removed from the bins or pits within any of the more densely populated parts of the District without a permit from the health officer. Any person violating any of the provisions shall, upon conviction thereof, be punished by a fine of not more than $40 for each offense.

Not only must horse stables be cared for, but chicken yards, piggeries, and garbage receptacles as well. In cities, with better methods of disposal of garbage and with the lessening of the number of horses and horse stables consequent upon electric street railways, bicycles, and automobiles, the time may come, and before very long, when window screens may be discarded.

DISPOSAL OF MANURE IN RURAL AND SUBURBAN DISTRICTS.

The control of flies in rural and suburban districts offers a much more difficult problem. Here it is out of the question to remove all manure from the premises twice a week. The problem is rather to find some method of disposal or storage which will conserve the fertilizing value of the manure and at the same time prevent all flies from breeding or destroy such as do breed there.

With this idea in mind, it has been recommended that stable manure be removed every morning and hauled out at once and spread rather thinly on the fields. This procedure is advisable from the point of view of getting the maximum fertilizing value from the manure. Immediate spreading on the fields is said largely to prevent the loss of plant food which occurs when manure is allowed to stand in heaps for a long time. This method will be effective in preventing the breeding of flies only if the manure is hauled out promptly every morning and spread thinly so that it will dry, since it is unfavorable for fly development in dessicated condition. Removal every three or four days will not be sufficient. Observations have shown that if manure becomes flyblown and the maggots attain a fairly good size before the manure is scattered on the fields, they can continue their development and will pupate in the ground. A further objection is that during the summer months, when fly breeding is going on most actively, the agriculturist is also busy and can seldom spare the time or the teams to carry out such a program regularly.

CHEMICAL TREATMENT OF MANURE TO DESTROY FLY MAGGOTS.

The general practice, therefore, is to remove manure and keep it in heaps located, as a rule, very near the stables. How can fly breeding be prevented in such accumulations? As a result of recent investigations, it is now possible to point out two methods which are practical and effective.

The first is the treatment of the manure pile with chemical substances which will kill the eggs and maggots of the house fly. The Bureau of Entomology, in cooperation with the Bureau of Chemistry and the Bureau of Plant Industry, has conducted a series of experiments in which a large number of chemicals were applied to infested manure and observations made not only on their efficiency in killing the maggots but also as to their effect on the chemical composition and bacterial flora of the manure. The object was to find some cheap chemical which would be effective in destroying the fly larvæ and at the same time would not reduce the fertilizing value of the manure.

TREATMENT WITH HELLEBORE.

Of the numerous substances tried, the one which seems best to fulfill these conditions is powdered hellebore. Some of the powdered hellebore in use is prepared from the roots of a plant which is popularly known as Indian polk or itch weed.[1] It is common in wet grounds and is of wide distribution in the United States. The European species of this plant,[2] however, furnishes the bulk of the supply. Hellebore contains a number of chemical compounds known as alkaloids. Alkaloids are organic substances, of which quinine, morphine, and cocaine may be mentioned as examples, which act very intensely on the animal body. For the treatment of manure a water extract of the hellebore is prepared by adding ½ pound of the powder to every 10 gallons of water, and after stirring it is allowed to stand 24 hours. The stock mixture thus prepared is sprinkled over the manure at the rate of 10 gallons to every 8 bushels (10 cubic feet) of manure. From the result of 12 experiments with manure piles treated under natural conditions it appears that such treatment results in the destruction of from 88 to 99 per cent of the fly larvæ. Amounts of hellebore less than ½ pound to every 8 bushels of manure are not so effective, while stronger applications, of course, will give somewhat better results.

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[1] *Veratrum viride.*

[2] *Veratrum album.*

Bacteriological studies of the treated piles proved that the bacteria were not injured or their development retarded, and chemical analysis showed that the composition of the manure was unaltered. Furthermore, several field tests were made in growing cabbages, turnips, lettuce, potatoes, wheat, and a few other crops on plats which had been fertilized with hellebore-treated manure, with the result that there appeared no injury whatever that could be ascribed to the use of this substance. The only possible objection to the use of hellebore seems to be the possibility of poisoning farm animals, as might happen if, for example, the barrel or tank in which the stock solution was prepared were left uncovered in an accessible place. It is quite safe to say that chickens will not be injured by pecking at hellebore-treated manure. This has been tested carefully. Hellebore can be obtained both in ground and powdered form, but the powdered form gives the best results in the destruction of fly larvæ.

TREATMENT WITH POWDERED BORAX.

Another chemical found to be even more effective as a larvicide is powdered borax. This is an inorganic substance, available in commercial form in all parts of the country. It has the advantage of being comparatively nontoxic and noninflammable and is easily transported and handled. The minimum amount necessary to kill fly larvæ was found to be 0.62 pound per 8 bushels of manure, or about 1 pound per 16 cubic feet. Best results were obtained when the borax was applied in solution, or when water was sprinkled on after the borax had been scattered evenly over the pile. Borax is not only effective in killing the larvæ, but when it comes in contact with the eggs it exerts a toxic action which prevents them from hatching. When applied at the rate of 1 pound to 16 cubic feet it was found to kill about 90 per cent of the larvæ, heavier applications killing from 98 to 99 per cent.

Borax had no injurious effect on the composition of the manure; in fact, in some cases the ammonia and water-soluble nitrogen seemed to be increased; nor was there any permanent decrease in the number of bacteria. Borax-treated manure was less subject to the growth of molds and consequent firefanging. Now, although borax does not have any deleterious effect on the chemical composition of manure, yet when added to the soil with the manure it acts directly on plants, and large applications will cause considerable injury. On the other hand, certain investigators have shown that small amounts of borax have a stimulating effect. The question is, therefore, whether any injury to plants will result from the application of manure treated at the rate of 1 pound per 16 cubic feet. To answer this point numerous tests were carried out, both in the greenhouse and under field conditions, using borax-treated manure for fertilizing a number of different crops, such as wheat, potatoes, peas, beans, lettuce, and others. As far as these experiments have gone they indicate that if manure so treated is applied at a rate of not more than 15 tons per acre, no injury, as a rule, will follow. Some plants are more sensitive to the presence of borax than others, however, and the effects are more noticeable on some soils than on others. All crops have not been tested, nor has the cumulative effect of borax treatment been worked out. It is necessary, therefore, to repeat the warning issued in connection with a previous bulletin on this subject, that great care be exercised, in the application of borax, that the manure does not receive more than 1 pound for every 16 cubic feet, and that not more than 15 tons of manure so treated are applied to the acre.

In view of the possible injury from the borax treatment as a result of carelessness in applying it, or from other unforeseen conditions, it is recommended that horse manure and other farmyard manures which are to be used as fertilizer be treated with hellebore. Borax, on the other hand, is such a good larvicide that it can be used with advantage on the ground of soil-floor stables, in privies, on refuse piles, and on any accumulations of fermenting organic matter which are not to be used for fertilizing purposes.

TREATMENT WITH CALCIUM CYANAMID AND ACID PHOSPHATE.

Many experiments with mixtures of commercial fertilizers were tried to determine whether fly larvæ would be killed by any substance the addition of which would increase the fertilizing value of the manure. A mixture of calcium cyanamid and acid phosphate was found to possess considerable larvicidal action. Several experiments showed that ½ pound of calcium cyanamid plus ½ pound of acid phosphate to each bushel of manure gave an apparent larvicidal action of 98 per cent. The mixture in the form of a powder was scattered evenly over the surface and then wet down with water. The use of this mixture adds to the manure the important elements, nitrogen and phosphorus.

Of course there are a number of other insecticides which are effective against fly larvæ. Potassium cyanid, Paris green, arsenite of soda, etc., are effective, but they are hardly to be recommended for general use because of their extremely poisonous nature. Others, like pyridine, aniline, and nitrobenzene emulsion, are too expensive when used in amounts sufficient to kill maggots.

MAGGOT TRAP FOR DESTRUCTION OF FLY LARVÆ FROM HORSE MANURE.

The second method of handling manure is one which does not require the application of chemicals. It is based on the fact, mentioned on page 6, that the larvæ of the house fly, when about ready to pupate, show a very strong tendency to migrate, leaving the spot where they have been feeding and crawling about in search of a suitable place for pupation. This migration takes place mostly at night, and the larvæ sometimes crawl considerable distances away from the manure pile. Now it is possible by means of a very simple arrangement called a maggot trap to destroy fully 99 per cent of all maggots breeding in a given lot of manure. A successful maggot trap which the Maryland Agricultural College constructed at the college barn is shown in figure 14. The trap was designed by the

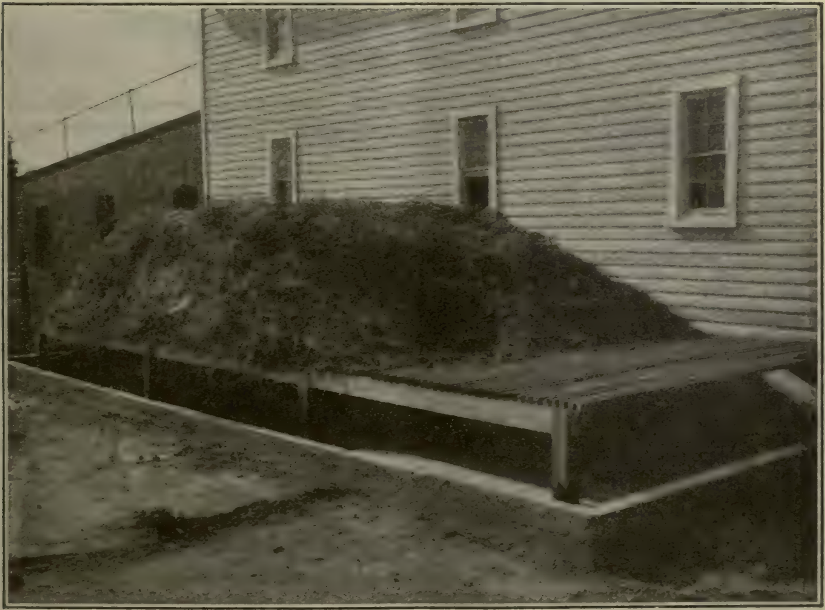

FIG. 14.—A maggot trap for house-fly control. View of the maggot trap, showing the concrete basin containing water in which larvæ are drowned, and the wooden platform on which manure is heaped. (Hutchison.)

junior author and constructed under his supervision. The manure, instead of being thrown on the ground, is heaped carefully on a slatted platform, which stands about 1 foot high. This particular platform measures 10 by 20 feet. There are six 2 by 4 pieces running lengthwise 2 feet apart. Across these are nailed 1-inch strips with ½ to 1 inch spaces between them. The wooden platform stands on a concrete floor, and a rim or wall of concrete 4 inches high surrounds the floor. The floor slopes a little toward one corner, from which a pipe leads to a small cistern near by. This pipe is plugged with a stopper of soft wood, and the concrete floor is filled with water to a depth of 1 inch in the shallowest part. The manure is then heaped on the platform each morning when it is removed from the stable. Flies will lay their eggs on the manure as usual, but the maggots, when they have finished feeding and begin to migrate, crawl out of the manure, drop into the water below, and are drowned. Each week the plug is removed from the pipe, and all the maggots are washed into the cistern. The floor is then cleaned of any solid particles by means of a long-handled stable broom or by a strong stream of water from a hose. The pipe being again plugged, the floor is again partly filled with water and the trap is ready for another week's catch. A platform of this size will hold the manure accumulating from four horses during the period of four months, or about 20 days' accumulation from 25 horses, if the heap is well built and made at least 5 feet high.

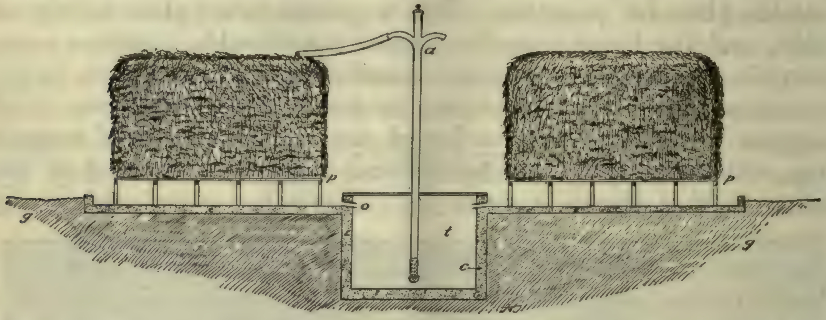

FIG. 15.—Imaginary cross section of an arrangement suggested for use where manure production is large. *a*, Pump; *c*, concrete floor and walls of cistern; *o*, outlet pipes leading from floor of maggot trap to cistern; *p*, platform maggot trap; *t*, cistern for liquid manure; *g*, ground level. (Hutchison.)

Experience with maggot traps has brought out the following points: In the first place, the trap is more effective when the manure is kept compactly heaped and well moist. This is to be explained by the fact that the larvæ seek a comparatively dry place in which to pupate, and crawl away from wet manure. A cistern should be built close to the trap and a pump fitted so that liquids can be pumped onto the heap. (Fig. 15.) Each day, after the litter from the stable has been thrown onto the heap, just enough water should be added to moisten it thoroughly without causing leaching. The ideal arrangement would be to have water-tight floors in the stalls and drains leading to the cistern. The liquid manure collecting in the cistern could be pumped onto the manure heap, thus not only maintaining the moisture content necessary to insure the greatest amount of migration, but also adding to the manure the valuable constituents of the urine. It happens, too, that keeping the manure carefully heaped and watered promotes the anaerobic fermentation and tends to prevent to some degree the loss of ammonia and gaseous nitrogen.

In the second place, the platform should stand not less than 1 foot above the concrete floor. This is to facilitate cleaning the floor of maggots and the débris which unavoidably accumulates there. The floor should be cleaned at least once a week, and all liquids run into the cistern in order to prevent mosquitoes from breeding in the water in the floor of the trap. A thin film of oil can be used to prevent mosquito breeding in the cistern.

A third point of importance is that old manure is unfavorable for fly breeding. Experiments have shown that after manure has been standing on a maggot trap for 8 to 10 days it is practically free from maggots, and no more will appear in it. This means that a given lot of manure need remain on the maggot trap for only 10 days in order to prevent any breeding taking place in it.

The maggot trap is simple, easily constructed, and cheap. Practically the only cost is the initial one for construction. Very little extra labor is required to operate it. Only a few minutes each day are necessary to water the manure after the stable cleanings have been added to the heap. Cleaning the floor to dispose of the maggots and to prevent mosquito breeding will take about half an hour once a week.

That the maggot trap is effective has been shown by the junior author's observations at the Maryland Agricultural College. It was found that the trap destroyed 99 per cent of the larvæ breeding there and that the number of flies at the barn and around the college kitchen was reduced 67 to 76 per cent. That the reduction in the prevalence of flies was not equal to the percentage of larvæ destroyed was ascribed to the fact that several other piles of untreated manure were breeding out flies at near-by stables, and from these places they were attracted to the barn and kitchen.

Maggot traps may be constructed in almost any size and to suit almost any conditions, and appear to be especially adapted to meet the problem of fly control under rural conditions.

COMPACT HEAPING OF MANURE.

Another method of disposing of manure has been recommended by English writers, as a result of experience in preventing fly breeding in the large accumulations of horse manure around army camps. A rectangular area of ground is staked off and the daily accumulations of manure are hauled on to this area, and dumped. It is then built up into a compact heap, the sides of which are straight and beaten hard with shovels. The ground around the edges of the heap is made smooth and hard and then some loose straw is placed in small windrows around the manure pile about 1 foot from the edge. By pressing down the manure into a compact heap, air is excluded from the interior. This condition, together with the high temperature and gases formed by fermentation, tends to make the heap an unfavorable place for the development of fly larvæ. Those which do happen to develop in the surface layers will migrate when fully fed and pupate in the ring of straw around the heap. This straw, with pupæ in it, is swept up every two or three days and burned.

TREATMENT OF MISCELLANEOUS BREEDING PLACES.

It is just as true under farm conditions as in cities that breeding places other than horse manure must be attended to. Garbage must be disposed of, hog and poultry manure must be cared for, and especially on dairy farms it is extremely important that every precaution be taken to prevent the contamination of milk by flies. Care and cleanliness, combined with some of the arrangements just described, will measurably affect the fly nuisance in neighboring buildings.

SEWAGE DISPOSAL IN RELATION TO THE PREVENTION OF FLY-BORNE DISEASES.

In the consideration of these measures we have not touched upon the remedies for house flies breeding in human excrement. On account of the danger of the carriage of typhoid fever, the dropping of human excrement in the open in cities or towns, either in vacant lots or in dark alleyways, should be made a misdemeanor, and the same care should be taken by the sanitary authorities to remove or cover up such depositions as is taken in the removal of the bodies of dead animals. For modern methods of sewage disposal adapted for farm use one should consult Department of Agriculture Bulletin No. 57, which may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 10 cents. In the absence of modern methods of sewage disposal, absolutely sanitary privies are prime necessities, whether in towns or on farms. Directions for the building and caring for such privies will be found in Farmers' Bulletin 463 and in Yearbook Separate 712, "Sewage Disposal on the Farm." The box privy is always a nuisance from many points of view, and is undoubtedly dangerous as a breeder of flies which may carry the germs of intestinal diseases. The dry-earth treatment of privies is unsatisfactory. No box privy should be permitted to exist unless it is thoroughly and regularly treated with some effective larvicide. Since the fecal matter in such privies is seldom used for fertilizing purposes it may well be treated liberally with borax. The powdered borax may be scattered over the exposed surface so as to whiten it. An application two or three times a week during the fly season ought to prevent all fly breeding in such matter.

WHAT COMMUNITIES CAN DO TO ELIMINATE THE HOUSE FLY.

Antifly crusades have been very numerous in recent years, and some have been noteworthy both in methods and in results. However, it will not be amiss here to emphasize the importance of concerted, organized effort on the part of whole communities, not only cities, but suburban and rural neighborhoods as well. By the most painstaking care one may prevent all fly breeding on his premises, but it will avail him little if his neighbors are not equally careful. Some sort of cooperation is necessary. One of the first and most important elements in any antifly crusade is a vigorous and continued educational campaign. It has been the experience of those who have undertaken such crusades that people generally regard the fly as a somewhat harmless nuisance and that the first work of the campaign was to bring the people to a realization of the dangers from flies and the possibility of getting rid of them. In the educational campaign every possible means of publicity can be employed, including newspapers, lectures, moving pictures, posters, handbills, cartoons, instruction in schools, etc.

The antifly crusade is a matter of public interest and should be supported by the community as a whole and engineered by the health officers. But health officers can do little toward the necessary work of inspection and elimination without funds, and therefore the support of the campaign must manifest itself in increased appropriations for public-health work. Very often it is lack of funds which prevents the health officers from taking the initiative in the antifly crusades, and there must necessarily be much agitation and education before they can profitably take up the work. Right here lies a field for civic associations, women's clubs, boards of trade, etc., to exercise their best energy, initiative, and leadership.

PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO HOUSEHOLD INSECTS.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Remedies and Preventives Against Mosquitoes. (Farmers' Bulletin 444.)
Some Facts About Malaria. (Farmers' Bulletin 450.)
The Sanitary Privy. (Farmers' Bulletin 463.)
The Yellow Fever Mosquito. (Farmers' Bulletin 547.)
The Carpet Beetle, or "Buffalo Moth." (Farmers' Bulletin 626.)
The House Centipede. (Farmers' Bulletin 627.)
Cockroaches. (Farmers' Bulletin 658.)
The True Clothes Moths. (Farmers' Bulletin 659.)
The Silverfish: An Injurious Household Insect. (Farmers' Bulletin 681.)
Fleas as Pests of Man and Animals, with Suggestions for Their Control. (Farmers' Bulletin 683.)
Hydrocyanic-acid Gas Against Household Insects. (Farmers' Bulletin 699.)
House Ants: Kinds and Methods of Control. (Farmers' Bulletin 740.)
The Bedbug. (Farmers' Bulletin 754.)
White Ants as Pests in the United States and Methods of Preventing Their Damage. (Farmers' Bulletin 759.)
Carbon Disulphid as an Insecticide. (Farmers' Bulletin 799.)
A Maggot Trap in Practical Use: An Experiment in House-Fly Control. (Department Bulletin 200.)
Further Experiments in the Destruction of Fly Larvæ in Horse Manure. (Department Bulletin 245.)
Argentine Ant: Distribution and Control in the United States. (Department Bulletin 377.)
European Earwig and Its Control. (Department Bulletin 566.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

The Migratory Habit of House-Fly Larvæ as Indicating a Favorable Remedial Measure. An Account of Progress. (Department Bulletin 14.) 1914. Price, 5 cents.
Experiments in the Destruction of Fly Larvæ in Horse Manure. (Department Bulletin 118.) 1914. Price, 10 cents.
Fleas. (Department Bulletin 248.) 1915. Price, 10 cents.
Termites, or "White Ants," in the United States: Their Damage and Methods of Prevention. (Department Bulletin 333.) 1916. Price, 15 cents.
Notes on the Preoviposition Period of the House Fly. (Department Bulletin 345.) 1916. Price, 5 cents.
Experiments during 1915 in the Destruction of Fly Larvæ in Horse Manure. (Department Bulletin 408.) 1916. Price, 5 cents.
Principal Household Insects of United States, with Chapter on Insects Affecting Dry Vegetable Foods. (Entomology Bulletin 4, n. s.) 1896. Price, 10 cents.
Notes on Mosquitoes of United States, Giving Some Account of Their Structure and Biology, with Remarks on Remedies. (Entomology Bulletin 25, n. s.) 1900. Price, 10 cents.
Economic Loss to People of United States Through Insects that Carry Disease. (Entomology Bulletin 78.) 1909. Price, 10 cents.
Preventive and Remedial Work Against Mosquitoes. (Entomology Bulletin 88.) 1910. Price, 15 cents.
Argentine Ant. (Entomology Bulletin 122.) 1913. Price, 25 cents.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1917

THE COMMON MEALYBUG AND ITS CONTROL IN CALIFORNIA

R. S. WOGLUM AND J. D. NEULS
Entomological Assistants, Investigations of Insects
Affecting Tropical and Subtropical Fruits

ERTY OF DIVISION OF
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VERSITY OF CALIFORNIA

FARMERS' BULLETIN 862

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. September, 1917

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NO ONE METHOD for the control of the common mealybug can be recommended under all conditions. The remedy or remedies to be used will depend upon whether the trees are in house lots or orchards, whether few or many, and the infestation light or severe. In the case of severe infestation it will depend also upon the kind of fruit. This insect infests oranges of all varieties, grapefruit, lemons, and all other kinds of citrus fruit grown in California, causing deformity, weakening and dropping of much immature fruit, and the discoloration and weakening of the rind of the fruit maturing.

This bulletin discusses the three remedies which have been widely used; namely, fumigation, spraying, and the artificial spread of insect enemies, points out the sphere of usefulness of each method, and shows, on pages 14–15, how they may be combined so as to secure complete control.

An important part of the procedure recommended is the banding of trees with a mixture consisting of sulphur and a sticky material used to protect trees from insects. This keeps off the Argentine ant and other ants which attend and foster the mealybug and hinder or prevent the good work of insect enemies which otherwise might hold it in check. The method of preparing the mixture and applying the bands is described on pages 12–14.

Where the insect enemies are few or absent, or where they are themselves heavily parasitized, the trees should be sprayed or fumigated, and colonies of effective enemies should be introduced.

THE COMMON MEALYBUG[1] AND ITS CONTROL IN CALIFORNIA.

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FAILURE of control methods against the common mealybug in California, together with its continued spread and the recent severe outbreak at Uplands, Cal., of a previously unknown species,[2] has caused mealybugs to be probably the most feared insect pests of citrus fruits in southern California to-day. The common mealybug is reported as destructive in Los Angeles, Orange, Santa Barbara, San Diego, and Ventura Counties. Fortunately, however, only a small percentage of the citrus acreage in these counties is now infested by this insect.

The common mealybug is of world-wide distribution and omnivorous habits. It appears first to have been reported in California as an orchard pest near Los Angeles more than 30 years ago, and subsequently came to notice in Paradise Valley, San Diego County. Its sporadic outbreaks continued to be of mere local concern until an extensive and severe infestation appeared in Ventura County in 1907-8, simultaneously with new but lesser areas of infestation in Los Angeles, San Diego, and Orange Counties.

NATURE OF INJURY AND HOST FRUITS PREFERRED.

A severe infestation of the common mealybug is well illustrated in figure 1 and in the illustration on the title-page. Immature fruit may be deformed or may become so weakened that it drops. Maturing fruit is frequently discolored, resulting in a high percentage of culls or fruit of low grade. The cottony secretion covering the egg masses is unsightly, and the sooty mold which develops in the honeydew exudations necessitates washing the fruit. Abnormal decay

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[1] *Pseudococcus citri* Risso.

[2] *Pseudococcus citrophilus* Clausen.

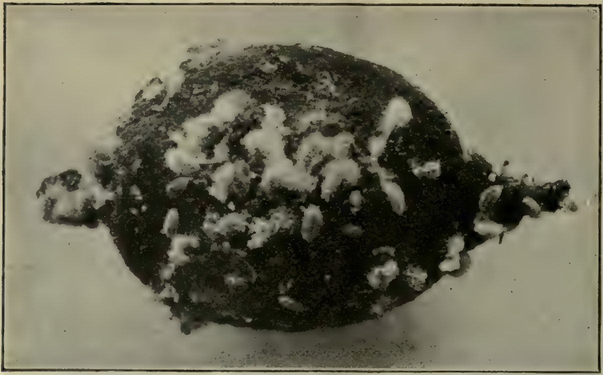

FIG. 1.—Lemon infested with the common mealybug.

usually follows the washing of this rind-weakened fruit. A severe infestation may result in partial or even complete defoliation of the trees. The lemon, grapefruit, and navel orange are preferred host fruits, although other varieties may be attacked severely.

CHARACTERISTICS AND LIFE HISTORY.

An idea of the superficial appearance of the common mealybug may be obtained from figure 2. The body of the insect is covered with a white waxy secretion, which is most pronounced in a bordering fringe of short filaments. The female retains the same general appearance through all stages of development from larva to adult. The male in its early stages is very similar to the female, but about four weeks after hatching it forms a cocoon, and from this it emerges, from 10 days to two weeks later, as a very small and delicate, light olive-brown, winged, gnatlike adult. Reproduction takes place from eggs deposited in a cottony sac secreted by the mature female. The number deposited depends on the size of the insect and varies from less than a hundred to more than a thousand, the average production of a female mealybug on green fruit being between 300 and 600 eggs. The length of a single generation on orange trees under the climatic conditions of Pasadena, Cal., during 1914–1916, varied from a minimum of 36 days during the summer to approximately six months during the winter. There are three more or less distinct generations a year on the citrus trees of southern California.

As a rule the infestations in the late winter and spring are so light as to escape notice, but later the crowding of the young insects on the small fruit, followed by the production of egg sacs in early summer, readily reveals the presence of the pest, and the maximum infestation and injury usually come in the early autumn with the second generation of mealybugs.

CONTROL OF THE MEALYBUG.

Three methods of control—fumigation, spraying, and the colonization of natural enemies—have played an important part in combating the mealybug on citrus trees and have been esteemed variously as the most promising. The studies carried on in southern California by this department indicate that no one of these control methods is applicable or preferable under all conditions of infestation, but by proper combination of these methods, and with the addition of banding to exclude ants, satisfactory control may be accomplished.

FUMIGATION.

Fumigation with hydrocyanic-acid gas as generally practiced for the black and red scales is a failure against mealybugs. No instance has been observed where the usual commercial treatment of an infested orchard with this gas has controlled this pest. Although records taken within a few weeks after fumigation have shown a reduction of the mealybug, such reduction was found invariably to be due largely to the action of natural agencies and doubtless would have occurred even though the trees had not been treated—a consideration seldom taken into account by the orchardist or commercial operator.

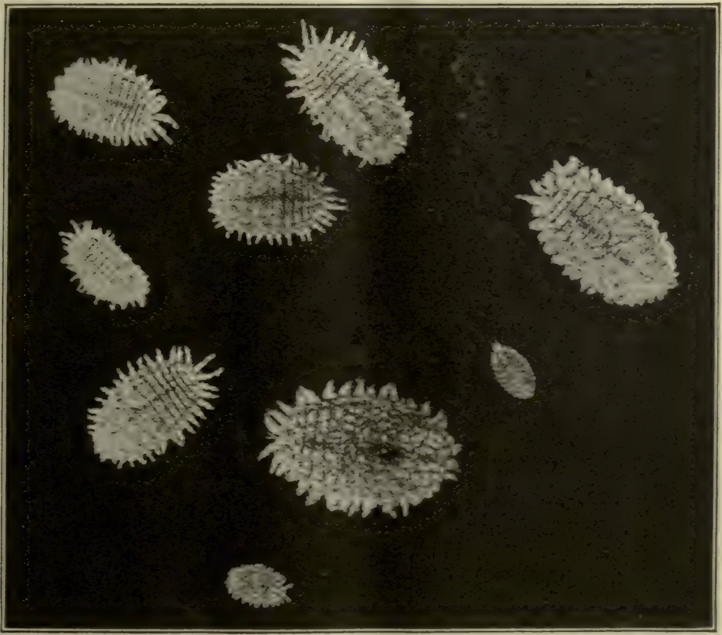

FIG. 2.—A group of common mealybugs. Enlarged about 9 times.

Table I sets forth the general results of experiments made to test the value of fumigation. The work was performed during the years from 1909 to 1917, under the climatic conditions normal to orchard fumigation in southern California.

TABLE I.—*Results of fumigation with hydrocyanic-acid gas against the common mealybug.*

A. 8-OUNCE U. S. ARMY DUCK TENT.

SINGLE CHARGE.

Dosage schedule.	Exposure.	Results.
No. 1[1]	1 hour	Small percentage killed. Commercially ineffective.
Two and three times No. 1.	do	85 to 95 per cent killed.

REPEATED CHARGE UNDER SAME TENT.

First charge.		Second charge.		Results.
Dosage schedule.	Exposure.	Dosage schedule.	Exposure.	
No. 1	30 minutes	No. 1	30 minutes	Small percentage living.
One and one-half times No. 1.	do	No. 1	1 hour	99 per cent killed.
No. 1	1 hour	No. 1	do	Do.

B. GAS-TIGHT TENT.

Sodium cyanid per 100 cubic feet.	Exposure.	Results.
1 ounce	1 hour	Sometimes a few living; usually all killed.
1½ ounces	do	All killed.

C. GAS-TIGHT BOX OF 100 CUBIC FEET CAPACITY.

¾ ounce	45 minutes	A number living.
¾ ounce	1 hour	A few living.
¾ ounce	2 hours	Sometimes a few living.
¾ ounce	4 hours	All killed.
1 ounce	45 minutes	Usually a few living.
1 ounce	1 hour	All killed.

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[1] This schedule is given on page 34 of Bulletin No. 90 of the Bureau of Entomology, U. S. Department of Agriculture.

These results show the ineffectiveness of single-dosage fumigations under army duck tents, even where excessive dosages are used. Repeated charges give better results but can not be recommended except in the case of a limited number of trees where other control measures are not readily available, or where cost and possible injury are secondary to immediate control. Since 8-ounce United States Army duck retains hydrocyanic-acid gas better than any other cloth of which fumigation tents are constructed at present, results equally poor in comparison with those tabulated are to be expected under drill or double-filled duck covers.

Treatment under gas-tight tents is eminently successful from the standpoint of general control, it being possible to secure complete eradication on a small number of trees, and such treatment would be recommended in preference to any other means of artificial control but for the fact that no gas-tight tenting material practical for commercial usage is known at present. It is to be hoped and expected that a suitable gas-tight cloth will be forthcoming in the future. The dosage should be 1 ounce of sodium cyanid to each 100 cubic feet of space beneath the tented tree; for eradication, 1¼ ounces.

Citrus trees in dormant condition during the winter months will withstand safely a dosage as high as 1¼ ounces of sodium cyanid to 100 cubic feet of space under gas-tight covers. Heavy, repeated dosages under ordinary commercial tents have been used at this time with little damage to the trees. It is unsafe, however, to apply such concentrated gas to orange or grapefruit trees during the growing season.

Eradication of the mealybug can be effected in a gas-tight box or room with a dosage rate of 1 ounce of sodium cyanid to each 100 cubic feet of space.

SPRAYING.

RECOMMENDED SPRAY FORMULAS.

More than 100 different sprays have been tried against the mealybug, including insecticides formerly used and others developed during this investigation. Several preparations, including the resin wash and a 2½ per cent paraffin-oil emulsion, have given fairly effective results; but two new sprays, cresolated distillate emulsion and soap-powder emulsion, are recommended as best measuring up to orchard requirements in mealybug control. The formulas for the preparation of these sprays are given below.

CRESOLATED DISTILLATE EMULSION.

Distillate (28° Baumé)	gallons	2¾
Liquor cresolis compositus, U. S. P	quarts	1¾
Liquid fish-oil soap	quart	1
Soap powder (sodium carbonate 40–60 per cent, caustic soda 40–60 per cent)	pounds	3
Water to make	gallons	100

Preparation.—When the bottom of the spray tank is covered with water, start the agitator and sift in the finely ground soap powder, which dissolves while the tank is filling. Prepare the stock by first measuring the distillate, then pour the liquor cresolis compositus into the distillate and stir. Pour into the liquid soap twice as much of the foregoing mixture as of the soap and beat with a paddle until of uniform consistency. Then add remainder of mixture and stir thoroughly, after which the preparation is ready to be poured into the spray tank.

This spray has been used with success for more than a year and is recommended as the preferred insecticide for mealybugs. It has been applied to a very large variety of plants during the winter season without injury. Oranges and lemons are treated safely, though grapefruit has been known to be stained slightly. The grade of distillate is very important, and only that of a gravity approximating 28° Baumé should be purchased. This is an untreated black oil, very distinct from the stove distillate (32°–34° Baumé), which is commonly used for spraying. The cost of cresolated distillate emulsion is about 1½ cents a gallon.

SOAP-POWDER EMULSION.

Distillate emulsion[1]	gallons	5
Soap powder	pounds	10
Water to make	gallons	100

Preparation.—When the bottom of the spray tank is covered with water, start agitator and sift in the finely ground soap powder. The distillate emulsion is added when the tank is almost filled.

Soap-powder emulsion is effective against the mealybug as well as against citrus scales. It is more injurious to the foliage than cresolated emulsion, however, and may cause moderate or even severe dropping of the leaves unless applied under favorable climatic conditions. (See "Season for spraying," p. 9.) The cost is about ¾ cent a gallon.

HOW TO SPRAY A TREE.

Trees first should be pruned of all dead wood and opened up so as to allow the ready use of the nozzle on the inside. In spraying for mealybug control the results accomplished are quite as dependent upon the method of application as upon the insecticidal properties of the material used. The upper, or dorsal, surface of the mealybug is tough and resistant to most commercially usable dips and sprays, the place of greatest vulnerability appearing to be a series of tubes which lie beneath the fringe of wax. This protective fringe, which is very resistant to most insecticides, must be removed by the spray to insure quick destruction of the insect; and to effect this removal careful treatment with a driving spray is required.

A power machine capable of maintaining 200 to 250 pounds pressure should be used. A very satisfactory type of nozzle is shown

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[1] Formula for distillate emulsion:

Distillate (28° Baumé)	gallons	20
Liquid fish-oil soap	do	4
Hot water	do	16

Pour hot water into spray tank. Start agitator, then add soap. Next slowly pour in distillate. Pump back into itself through nozzle for 20 minutes, after which pump through fine nozzle into storage tank. This emulsion keeps indefinitely.

in figure 3. The rods for spraying the inside and lower parts of the trees should not exceed 6 feet in length.

Mealybug infestation is confined in large part to the fruit, especially that toward the inside of the tree. It is recommended that the inside of the tree be sprayed first, starting at the lower part and moving upward, and then finishing over the outside of the tree. Especial effort should be made to spray the top of the tree, where the insects are most likely to escape treatment. Trees more than 10 feet in height should have their tops sprayed from a platform on the sprayer or from a light tripod ladder which can be carried from tree to tree. The nozzle should be moved rapidly about the tree, the spray being directed against both sides of the leaves, against the fruit from at least two directions, and in all crevices which may harbor mealybugs. Thoroughly to spray a citrus tree 10 to 15 years old usually requires fully 20 gallons of material.

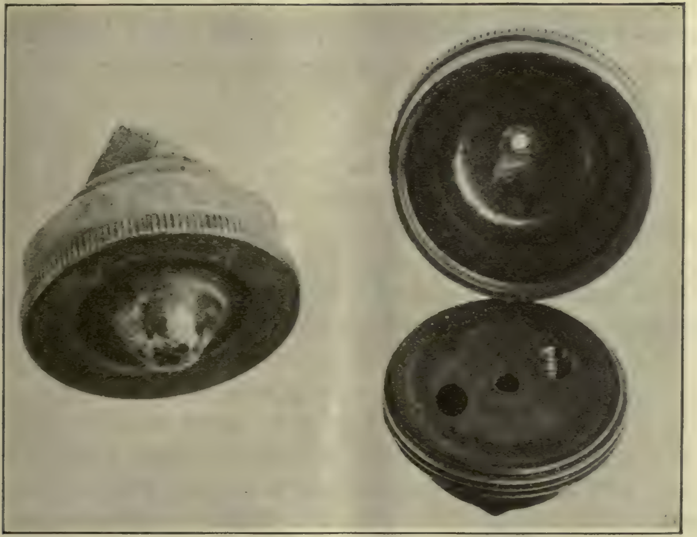

FIG. 3.—A type of nozzle well adapted to mealybug spraying.

SEASON FOR SPRAYING.

Insecticidal sprays of the strength required to destroy the common mealybug may be applied safely to citrus trees in California only during the cool months of the year, when the fruit is either maturing or has been picked. This season generally extends from November to April, though the months of greatest plant resistance to sprays are December, January, and February. It is unsafe to apply the insecticidal sprays advocated in this bulletin when the temperature is above

80° F. or during the summer when the trees are laden with immature fruit. Should it appear advisable to employ a spray during the summer, water under pressure should be used, as this can be applied safely, even when the highest summer temperatures prevail.

WATER SPRAYING.

An increasing number of growers are using successfully water under pressure so as to dislodge the mealybugs forcibly from citrus trees. This method of control was demonstrated in several orchards during the years 1915 and 1916, with varying degrees of success. Control of mealybugs by water spraying is practicable in the case of all citrus fruits excepting possibly the navel orange, but its success depends on thorough and repeated applications. Especially is this true of the navel orange, which requires such a large number of applications that the method is generally impractical in extensive and severe infestations.

Water has one important advantage over all other sprays in that it may be used with safety in unlimited quantities at any time of the year, thus affording a means of combating mealybugs during the summer months when practically all insecticides of value are too injurious to fruit and foilage to justify their application.

Several matters have a very important bearing on the successful commercial use of water spraying. In orchards the cost can be reduced materially by installing a system of piping, the power being derived from the water main, a stationary pump, or a power sprayer. The piping should be of a diameter to give ample force. The best type of nozzle allows an uninterrupted flow through an aperture not larger than one-fourth of an inch. The writers devised a very satisfactory direct-discharge nozzle having a rectangular opening 6 by 2 millimeters and capable of delivering 6 to 7 gallons a minute under 100 pounds pressure. The common garden type or a ¼-inch fire nozzle, however, will serve the purpose. Nozzles with small openings, as those of the Bordeaux type, are unsuitable for water spraying, as the stream of water will strip the leaves and cut off fruit. The tops of the trees should be sprayed from a ladder. Twenty to thirty minutes are required for spraying thoroughly a tree 10 to 15 years old.

CONTROL BY NATURAL ENEMIES.[1]

No important citrus insect pest in California seems to be attacked by more natural enemies than the mealybug, and efficient control of the mealybug by these natural enemies is often noted. For example, one severely infested orchard was observed to be cleaned in less than two months to an extent satisfactory in commercial control by two species of predatory brown lacewing flies.[1] Other groves have enjoyed similar respite from mealybug injury through the activity of these brown lacewings, aided by one or the other of two species of ladybird beetles.[2] Undeserved credit is often given to insecticides, in the case of orchards that have contained these natural enemies in large numbers at the time of spraying or fumigation, while in fact the mealybugs have been destroyed by these predatory enemies unobserved by the orchardist or operator. The natural enemies are most efficacious during the autumn and early spring.

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[1] The more effective enemies of this species, including both predators and parasites, given in the order of their importance, are: *Sympherobius barberi* Banks, *S. californicus* Banks, *Hyperaspis lateralis* Muls., *Cryptolaemus montrouzieri* Muls., *Chrysopa californica* Banks, *Leucopis bella* Loew, and *Paraleptomastix abnormis* Girault.

RELATION OF ANTS TO NATURAL CONTROL.

Since the mealybug is beset with so many efficient natural enemies, it has been the cause of considerable wonder that the pest is not more generally kept in check. The infestation may be reduced during the autumn or spring to a point bordering on control or even eradication, yet it is a matter of common observation in some localities that in spite of these conditions one severe infestation follows another year after year. This failure of the natural enemies to hold the mealybug in check throughout the year has been found to be due mainly to the presence on the trees of large colonies of ants, the Argentine ant [3] being the greatest offender. The experimental work reported in this bulletin has been confined to the Argentine ant, which has been observed to carry living mealybugs, to destroy and carry off the larvæ and eggs of natural enemies, to interfere with the free movement about the tree of certain beneficial insects, and by their constant attendance upon the mealybugs to prevent normal egg laying and feeding of the adult parasites and predatory enemies.

Remarkable results have been secured by keeping the Argentine ant off of trees infested with mealybugs by banding with a sticky mixture. In Los Angeles County during 1915 and 1916 trees that when first freed from ants were infested severely with the mealybug became commercially clean, without exception, within a period of six weeks to three months. The mealybug remained under control throughout the year or during the period of the experiments, while trees in adjacent check rows only a few feet away continued to be severely infested. The natural enemies responsible for this control were the two brown lacewings and a ladybird beetle.[4]

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[1] *Sympherobius barberi* Banks and *Sympherobius californicus* Banks.

[2] Either *Hyperaspis lateralis* Muls. or *Cryptolaemus montrouzieri* Muls.

[3] *Iridomyrmex humilis* Mayr.

[4] *Hyperaspis lateralis* Muls.

An experiment typical of many others is given in Table II.

TABLE II.—*Relation of the Argentine ant to the natural control of the mealybug. Experiments at Sierra Madre, Cal., July to October, 1916.* [*Percentage of fruit infested with the mealybug on each tree. Twenty orange trees to each test.*]

I. NO INSECTICIDAL TREATMENT.

Tree No.	1	2	3	4	5	6	7	8	9	10
Infestation at start of test, July 25. All trees frequented with ants:										
a. Check row, unbanded	100	100	94	80	34	90	100	100	91	100
b. Banded	92	96	92	86	100	73	82	75	93	100
Six weeks after start, Sept. 6:										
a. Check row, unbanded	100	92	80	91	73	100	100	86	90	100
b. Banded	1	3	2	1	15	1	2	1	......	24
Eleven weeks after start, Oct. 11:										
a. Check row, unbanded	100	82	45	50	32	61	96	76	42	86
b. Banded [1]	0	1	0	0	1	0	1	0	0	1

[1] Only 8 infested fruit on entire 10 banded trees.

II. TREES SPRAYED WITH WATER ON JULY 25.

	1	2	3	4	5	6	7	8	9	10
Condition before water spraying, July 24:										
a. Unbanded	94	100	97	100	100	100	85	100	100	100
b. Banded	30	98	100	90	55	93	89	100	100	86
Six weeks after start, Sept. 6:										
a. Unbanded	100	95	94	99	100	98	100	59	100	94
b. Banded	2	1	9	2	1	4	14	1	3	5
Eleven weeks after start, Oct. 11:										
a. Unbanded	90	93	92	90	94	100	100	20	100	100
b. Banded	1	0	1	0	0	0	1	0	0	0

HOW TO KEEP ANTS OFF OF TREES.

To free trees of ants the ideal procedure would be to eradicate these insects from the area affected. The writers have not carried on any such tests, but the published results of work carried on by the Department of Agriculture against the Argentine ant[1] would indicate the feasibility of freeing orchards of this pest.

The procedure followed with noteworthy success in municipal control work was the distribution throughout the affected area of a poisoned sirup in a suitable container. A paraffined paper bag, with perforations for the passing of ants, containing about a gill of sirup, was used as a container for nailing to trees.

The sirup is made as follows:

Granulated sugar	pounds	15
Water	pints	7
Tartaric acid (crystallized)	ounce	¼
Boil for 30 minutes. Allow to cool.		
Dissolve sodium arsenite (C. P.)	ounce	¾
In hot water	pint	1
Cool. Add poison solution to sirup and stir well. Add to the poisoned sirup:		
Honey	pounds	1½
Mix thoroughly.		

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[1] Barber, E. R. The Argentine Ant: Distribution and Control in the United States. U. S. Dept. Agr. Bul. 377. 23 p., 4 fig. 1916. Newell, Wilmon, and Barber, T. C. The Argentine Ant. U. S. Dept. Agr. Bur. Ent. Bul. 122. 98 p., 13 pl., 13 fig. 1913.

A number of experiments with banding in orchards infested with the Argentine ant have proved the practicability of this method of keeping trees free of ants during their active season, and this method of control is recommended (see fig. 4) as the most effective one tried. Before the band is applied the tree should be pruned so that the lowest branch is fully a foot above the ground, and all rubbish should be removed from beneath the tree and the soil cultivated to destroy all grass and weeds. The only banding material which has given satisfaction is a mixture[2] made up as follows:

Finely powdered flowers of sulphur	part by weight	1
Commercial tree-banding sticky material	parts by weight	6

The two ingredients are mixed together thoroughly with a wooden paddle until of a uniform color and consistency. That possible injury may be avoided, this is not applied directly to the bark, although direct application of the commercial sticky tree-banding material alone has never been noted in California to affect citrus trees seriously. First coat the trunk with a thin layer of paraffin and apply the mixture of sulphur and sticky tree-banding material over this. Paraffin that has a high melting point is preferable, and it is applied with a brush while melted. It hardens almost immediately, after which the mixture just referred to can be applied in a band about 5 inches wide and almost one-fourth inch thick. A single application of this material has kept trees free of ants for several months during warm weather.

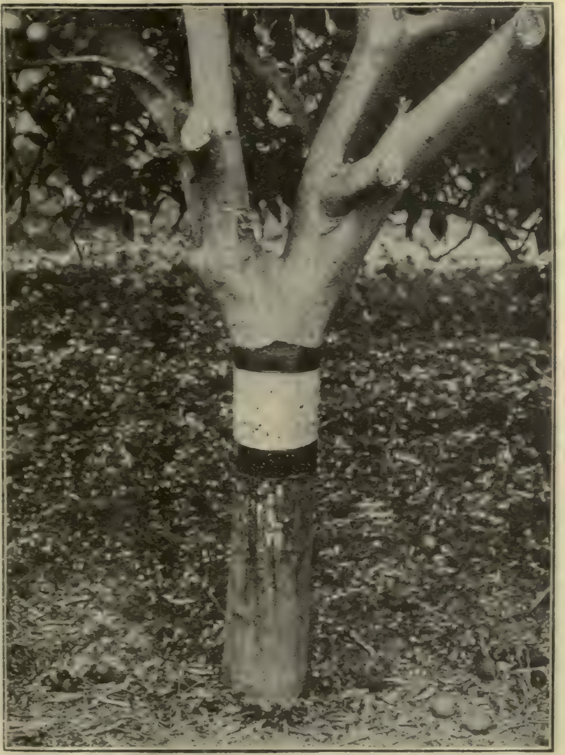

FIG. 4.—Keeping ants off citrus trees. A 5-inch band of sulphur and commercial sticky tree-banding material over a wider coating of paraffin.

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[2] Compounded by Mr. J. R. Horton of the Bureau of Entomology, U. S. Department of Agriculture. (See Horton, J. R. Some weatherproof bands for use against ants. *In* Mo, Bul. Cal, State Com. Hort., v. 5, no. 11, p. 419–421. 1916.)

Ants that are on trees at the time of banding usually drop off within a day or two unless nests are in the trunk or branches. If nests are present, however, they should be destroyed by applying pyrethrum or some other ant powder, or with a fine spray of gasoline from a plumber's torch, or with cresolated emulsion applied with a 3-gallon compressed-air sprayer. This should be done early in the morning, while the ants are least active.

Inspection should be made weekly for the discovery of reinfested trees, the bands being renewed where necessary and the branches of the trees kept from coming in contact with weeds or the ground.

GENERAL RECOMMENDATIONS.

In view of the success secured in the foregoing experiments in controlling the mealybug by keeping ants off of the trees, the impression might be conveyed that banding alone is all that is necessary to keep orchards commercially free of this destructive pest. Under present conditions this would probably prove true in most cases; nevertheless, two important factors must be kept in mind when a general scheme of control for the common mealybug in southern California is under consideration: (1) The possible scarcity or absence of effective beneficial insects in the infested orchard and (2) heavy parasitism of the beneficial natural enemies themselves in some localities at certain seasons of the year. Control of the mealybug under either of these conditions could not be effected quickly except by spraying or other artificial control, unless it should be possible to introduce promptly large colonies of effective natural enemies.

General recommendations for control are given below, and it is believed that complete success will result if they are followed closely in all details. Frequent examinations to detect ant reinfestation must be made, and colonization of natural enemies, where not present already in noticeable numbers, is essential. The trees should be sprayed wherever the conditions demand it.

PROCEDURE RECOMMENDED FOR THE CONTROL OF THE COMMON MEALYBUG.

TREES IN ORCHARDS.

1. Where there are very few trees.
    - *a.* Prune heavily for spraying, with lowest branches at least 1 foot above ground.
    - *b.* Band trees with sulphur-sticky mixture and keep them free of ants.
    - *c.* Attempt eradication by spraying with cresolated emulsion or by fumigation under a gas-tight tent.
    - *d.* Inspect weekly. If living insects are present, respray or refumigate until they are eradicated.

2. Where there is a light general infestation.
    - A. Where no trees are severely infested.
        1. Pick navel fruit, including all culls and off bloom, before March 1.
        2. Band trees with sulphur-sticky mixture, preferably in February or March. Free trees of ants.
        3. Introduce large colonies of the four most useful insect enemies,[1] if these are not present in noticeable numbers. This should be done preferably in March or April, but introduction can be continued throughout the season, if necessary.
        4. Inspect weekly for ant reinfestation.
        5. Spray with water during summer, if infestation becomes severe.
    - B. Where there are a few severely infested trees in an orchard otherwise lightly infested.
        1. Such trees should have the infestation greatly reduced during the month of February, either by spraying with cresolated or soap-powder emulsion or by fumigation under a gas-tight tent. Afterwards they can be handled like the rest of the orchard, as explained in A above.
3. Where there is severe infestation.
    - A. Treatment of navels, grapefruit, and lemons.
        1. *Navels and grapefruit.*—Pick all fruit, including culls and off bloom, before treatment. Leave culls and off bloom on the ground.
           Lemons.—Pick all marketable fruit before treatment.
        2. Prune heavily for spraying, with the lowest branches at least 1 foot above the ground.
        3. Following removal of fruit, spray with cresolated or soap-powder emulsion, or fumigate under a gas-tight tent, preferably in February.
        4, 5, 6, 7. The same as for *A* 2, 3, 4, and 5, respectively, in section 2.
    - B. Treatment of Valencias.
        The procedure is the same as for navels, grapefruit, and lemons, except that the fruit is not picked, while the spraying should be done with cresolated distillate emulsion.

TREES IN HOUSE LOTS.

1. Pick all fruit during the winter.
2. Prune heavily and keep free from buildings, other plants, etc.
3. Fumigate with eradication dosage under gas-tight tent if available. Otherwise spray heavily with cresolated or soap-powder emulsion.
4. Band with sulphur-sticky mixture and keep free of ants.
5. Spray frequently with water if living insects continue on trees.

PREVENTING SPREAD THROUGH PICKING BOXES AND BY PICKERS.

The present localization of the common mealybug renders advisable the adoption of some means to prevent its spread to new regions through such controllable agencies as picking boxes and picking sacks. Picking boxes which have been known to carry fruit infested with the mealybug should be treated before use in uninfested orchards. Eradication of this insect on boxes is secured by fumigation in a gas-tight room with hydrocyanic-acid gas at the rate of 1 ounce of sodium cyanid to each 100 cubic feet of space, or with sulphur at the same strength.

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[1] *Sympherobius californicus, S. barberi, Hyperaspis lateralis,* and *Cryptolaemus montrouzieri.*

Dipping picking sacks, gloves, and jumpers in gasoline for five minutes will destroy all insects and eggs. As the gasoline evaporates in a few minutes, the cloth or leather will be ready for use again before the next orchard is reached.

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University of Maine

Maine Agricultural Experiment Station

ORONO

BULLETIN 265 OCTOBER, 1917

THE BIOLOGY OF THE ALDER FLEA-BEETLE

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† In collaboration with U. S. Department of Agriculture.

BULLETIN 265

THE BIOLOGY OF THE ALDER FLEA-BEETLE, Altica bimarginata Say.[1]

WILLIAM COLCORD WOODS[2]

OCCURRENCE AND DISTRIBUTION.

Almost one hundred years have passed since Thomas Say (1842) first described the alder flea-beetle, *Altica bimarginata* Say,[3] but although periodically this insect appears in enormous numbers, no detailed work on its life history has yet been published, despite its wide distribution.

In the United States this beetle occurs from Maine to California, and it has also been reported from Canada. The following list includes all of the published distributional records which the writer has found: Maine (Packard 1890, Johannsen 1912); New Hampshire (Harris 1869, Packard 1890); New York (Linter 1887, Felt 1905, Britton 1911); Minnesota (Lugger 1899); Iowa (Sturm 1843); Missouri (Say 1824); Nebraska (Bruner 1893); Kansas (Le Conte 1859, 1860); New Mexico (Le Conte 1859); Oregon (Le Conte 1860); California (Mannerheim 1843, Le Conte 1857, 1860, Essig 1915); Mackenzie River Region, Canada (Le Conte 1860, Gibson 1913); British Columbia, Canada (Gibson 1913); Alberta, Canada (Gibson 1913); Nova Scotia, Canada (Gibson 1913).

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[1] Papers from the Maine Agricultural Experiment Station: Entomology No. 93.

Contribution from the Entomological Laboratory of Cornell University.

[2] Member of the Station Summer Staff.

[3] *Altica bimarginata* Say. Jour. Acad. Nat. Sci. Phila. 1824. V. 4, p. 85.
alni Harris. Ent. cor. ed. Scudder, 1869, p. 267.
ambiens Le Conte. Col. Kans. 1859, p. 25.
carinata Sturm. Cat. 1843, p. 282.
plicipennis Mannerheim. Bul. de Moscou, 1843, p. 310.
prasina Le Conte. Rept. Pac. R. R. Survey. 1857, p. 67.
subplicata Le Conte. Col. Kans. 1859. p. 25.

Altica[1] is the type genus of Alticini, one of the tribes into which the family Chrysomelidae, the leaf-beetles, is commonly divided. The members of this tribe are popularly known as flea-beetles because of their extraordinary powers of leaping, due to the strong muscles enclosed in the greatly enlarged femora of their hind legs. While Geoffroy (1762) stated that these insects could "jump with the agility of fleas", the first writer who actually referred to them as flea-beetles, seems to have been DeGeer (1775) who wrote "In Sweden they are known under the name Lopp-mask, that is to say, flea-beetle."

Among the European species of *Altica,* the injurious turnip-fly, *A. nemorum* Fab., is the best known, and of our American forms the destructive grape-vine flea-beetle, *A. chalybea* Ill., is a familiar example. Besides *A. chalybea,* at least two other species of *Altica* in addition to *bimarginata* Say occur in this state, the biology of which will be discussed in a forthcoming bulletin of this Experiment Station.

Although the alder flea-beetle is usually rather scarce, it may occur more or less periodically in enormous numbers, as has been intimated above. The first recorded outbreak was noted by Harris (1869) while he was traveling in New Hampshire, near Conway. Lintner (1888) gave an interesting account of the depredations caused by this species near Elizabethtown, N. Y., in 1877, and around Lake Pleasant, N. Y., in 1887. Packard (1890) mentioned this species as very abundant in Maine and New Hampshire in 1886 and 1887.

Similar outbreaks occurred in the State of Maine during the years from 1912 to 1915, and the observations recorded in this paper were made during those summers. The first specimens which were referred to the Experiment Station were sent in from Pan's Hill, Maine, in mid-July 1912. Later in the season, the beetles and their larvae were found working extensively on the alders in the Bangor Bog, near Orono. In 1913 they were extremely abundant all through the township of Orono and in many other parts of the state. The writer observed them in the townships immediately east of Orono, as far north as Mattawamkeag, and as far west as Oakland. They were not found in Lewiston, nor in Hancock and Washington Counties. Mr. John D. Tothill informed me that the beetles were present and abundant in New Brunswick, and Dr. Robert Matheson, in Nova Scotia.

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[1] A discussion of the synonymy of the genus *Altica* Geoffroy, with the reasons for changing the name from *Haltica,* will be found on page

So far as Maine is concerned, the year of maximum abundance was 1914. Even in the single township of Orono, the individuals of this species must have numbered many millions. The leaves were riddled by the attacks of the hibernating adults even before the larvae appeared. By the middle of August practically all of the leaves of every alder bush in the township had been skeletonized by the larvae, and the trees looked brown and bare, as though they had been swept by a fire. Many of the leaves had dropped from the trees, forming a mat half an inch or more thick under alder clumps. Some idea of the abundance of these insects may be obtained from the following data, which represent typical cases, illustrative of the condition of all of the shrubs in an alder copse covering several acres: on a twig selected at random, on which only the three last leaves were left, were found 115 larvae, 31 on the terminal leaf, and 56 and 28 respectively on the other two; on a single large leaf close by were counted 77 larvae. By the first of September the trees were practically leafless. The majority of them had put out new leaves which were eaten by the beetles as fast as they were produced. Such a serious infestation killed many of the trees even in a single season.

In the summer of 1915, there was a great reduction in the number of the beetles, and although they were still common locally, their range was so much restricted, that the writer knew but few localities in the whole township where he could obtain these insects. They were so rare in 1916 that even with diligent searching the writer found no larvae and only a single adult in Orono, and this condition seemed to be typical of that prevailing all over the state.

The writer can offer no satisfactory explanation of this extraordinary disappearance. It certainly was not due to any failure of the food supply through over-population, nor was it due to the activities of natural enemies, for the parasitic forms preying upon these insects were not sufficiently abundant to cause a wholesale destruction, and they are but little troubled by birds. Climatic conditions in the winter of 1914–15 were far from favorable, yet this can hardly be postulated as the cause of their disappearance, as it seemed to have little if any effect on the abundance of other species of *Altica.* The summer of 1915 was a favorable one for the growth of fungi, and many larvae and some adults were killed in this fashion, but the alder flea-beetle is not more suspectible to fungous attacks than other members of the genus whose numbers remained undiminished. However this species was much more abundant than any of the others, and on that account fungus could work much more effectively. Undoubtedly the fungus played a large role in checking the outbreak.

There is one peculiar circumstance which should be noted in this regard, as it seems to be correlated with the disappearance of *A. bimarginata.* As is pointed out under another heading, most of the eggs of these flea-beetles are deposited within the leaf-rolls of an alder caterpillar,*Acrobasis rubrifasciella* Packard. So far as the writer has observed, the abundance of this larva on the alder almost parallels that of the alder flea-beetle. It was abundant in 1912 and 1913, and very abundant in 1914; it was somewhat less common in 1915, and scarce in 1916. Whatever may have been the complex of conditions acting as determinative factors, the same conditions which acted as a check on the abundance of *Altica bimarginata* Say apparently acted also as a check on *Acrobasis rubrifasciella* Packard, and the abundance of the two species was evidently closely correlated.

Fortunately these beetles are not yet of great economic importance. The alder is not used commercially, and so long as the depredations are confined to it, the beetles cause no great injury, except where the alders have been used for ornamental planting in landscape gardening. But as is pointed out later, they can live on willow and probably on balsam poplar; and whenever this species is abundant, there is always the possibility that it may become a serious pest, should the beetles transfer their ravages either to the willow or to the poplar, both of which are of commercial importance.

THE LIFE HISTORY OF THE INDIVIDUAL.

Summary of the Life History.

The adult *Altica bimarginata* is a dark shiny steel blue flea-beetle, which can be distinguished from all other species in our fauna by the longitudinal plica or fold on the side of the elytra. Like the greater number of other chrysomelids, these beetles hibernate as adults; in Maine they seek winter quarters in late September, and emerge in the spring as soon as the alder leaves, on which they feed voraciously, are well expanded. Pairs may be taken in copulation from the first of June until early July. From mid-June until late July the females deposit clusters of yellow eggs on the foliage which hatch in a few days into grubs or larvae which skeletonize the leaves. The larval life extends over a period of about 25 days, during which they molt twice; there are, therefore, 3 larval instars. When the grubs are full grown, they enter the ground and construct a rude cell, in which they pass about 6 days as prepupae and 10 days as pupae. At the end of that time the adults appear. Before they seek hibernating quarters, the beetles feed freely on the leaves of the alder, which is the preferred food-plant of this species. There is but one generation each year.

Seasonal History and Biological Data.

DURATION OF THE EGG STAGE.

A record which was kept of 476 eggs deposited between June 16 and July 20, inclusive, may be tabulated as follows:

87 hatched in 7 days; 207, in 8 days; 157, in 9 days; 25, in 10 days; average 8.3 days.

LENGTH OF THE FIRST LARVAL INSTAR.

A record which was kept of 425 larvae which hatched between July 13 and July 28 inclusive, may be tabulated as follows:

182 molted to the second instar in 5 days; 115, in 6 days; 31, in 7 days; 18, in 8 days; 73, in 9 days; 6, in 10 days; average 6.3 days.

LENGTH OF THE SECOND LARVAL INSTAR.

A record which was kept of 340 larvae which molted to the second instar between July 18 and July 30 inclusive may be tabulated as follows:

65 molted to the third instar in 7 days; 210, in 8 days; 65, in 9 days; average 8.0 days.

LENGTH OF THE THIRD LARVAL INSTAR.

A record which was kept of 95 larvae which molted to the third instar between July 27 and August 30 inclusive may be tabulated as follows:

5 entered soil in 9 days; 11, in 10 days; 3, in 11 days; 11, in 12 days; 4, in 13 days; 38, in 14 days; 11, in 15 days; 12, in 16 days; average 13.2 days.

LENGTH OF PREPUPAL PERIOD.

A record which was kept of 215 prepupae which entered the soil between August 7 and August 30 inclusive may be tabulated as follows:

9 pupated in 4 days; 19, in 5 days; 82, in 6 days; 56, in 7 days; 11, in 8 days; 11, in 9 days; 6, in 10 days; 8, in 11 days; 6, in 12 days; 3, in 13 days; 2, in 14 days; 0, in 15 days; 1, in 16 days; 0, in 17 days; 1, in 18 days; average 7.0 days.

LENGTH OF THE PUPAL STAGE.

A record which was kept of 34 pupae which transformed between August 11 and September 6 inclusive may be tabulated as follows:

2 adults emerged in 8 days; 7, in 9 days; 1, in 10 days; 18, in 11 days; 5, in 12 days; average 10.2 days.

VARIATIONS IN THE REQUIRED TIME.

It was observed that whether the eggs were deposited early or late in the season had no bearing on the number of days occupied by the different instars, nor did the length of any given instar affect the length of the next instar. However, if the third instar were of short duration, the prepupal period tended to be longer than normal, and conversely. The principal factors causing variation were the conditions of temperature and moisture.

Nevertheless there is great variation in the length of time which different individuals require for reaching maturity. This is true even in the case of larvae hatching from a single egg cluster, or from different egg clusters but on the same day. For example, from eggs which hatched on July 17, 11 prepupae were obtained on August 11, 25 on August 13, 4 on August 14, and 11 on August 15; 9 pupae were removed on August 17, 5 on August 19, 4 on August 20, 1 on August 21, and 1 on August 22.

The following is cited as a typical life-history:
6 eggs which were deposited on July 22 (1914) hatched on July 30.
The larvae molted to the second instar on August 11.
The larvae molted to the third instar as follows:
1 on August 19; 1 on August 21; 2 on August 23; 2 on August 24.
The larvae entered the soil as prepupae, as follows:
1 on August 27; 1 on August 28; 1 on August 31; 3 on September 1.
Pupae were formed as follows:
3 on September 3; 2 on September 5; 1 on September 6.
Adults emerged as follows:
1 on September 13; 1 on September 14; 1 on September 15; 2 on September 16; 1 on September 17.

SEASONAL HISTORY IN MAINE.

The earliest date on which the writer has found eggs of the alder flea-beetle in Maine is June 16 (1915), but since he has collected recently hatched larvae on June 18 (1915), eggs must be deposited at least as early as June 10. The maximum period of egg deposition is early July. The latest date on which eggs were deposited in the laboratory is July 29 (1915), when only three eggs were obtained from many females which had been ovipositing freely. No unhatched eggs were found in the field at a later date. The oviposition period extends over a period of about a month and a half: from mid-June until late July.

Just hatched larvae were common on June 20 (1915). Larvae may be found commonly in the field as late as mid-August in years when this insect is abundant. No larvae have been found in the field later than August 24 (1914), although the writer has had them in the laboratory as late as August 30 (1914). The great majority of the larvae become full grown in late July or the first half of August.

The earliest date on which the writer has obtained pupae of this species is August 5 (1914). Without doubt this is much too late to be representative. Larvae entered soil in the laboratory on July 25 (1914), and if they had been allowed to develop should have formed pupae on July 31. Eggs deposited on June 10 should produce pupae on July 21 since 41 days is the average length of time required between the deposition of the eggs and the pupal transformation. This estimate is probably not far from correct, as eggs deposited on July 4 (1915) yielded pupae on August 13 (40 days). The majority of these insects pass through the pupal stage in August; the extreme records which the writer has for just-formed pupae are August 5 (1914) and September 6 (1914). As was pointed out, July 21 would doubtless be nearer the range of possibilities than August 5.

Nearly all of the hibernating adults are dead by late July. The latest date to which one lived in the laboratory is August 17 (1914). Adults become common again about the middle of August, and this undoubtedly represents the appearance of a new generation of the beetles. No adult which was bred in the laboratory emerged earlier than August 20 (1914), but pupae formed on July 21 should give adults on August 1. The extremes of emergence are probably represented by August 1 and September 7.

There is only one generation each year. There is no tendency to pair among the individuals of the new generation, and there is no indication that any of the pupae live over in the soil until the following summer. Since they pupate very near the surface in only the rudest sort of a cell, and since the pupal life normally lasts but a few days, one would not expect any of them to winter over. In the laboratory it was clear that all of the pupae which did not transform were unhealthy.

The writer was not able to make personal observations as to the time when the beetles seek winter quarters in the fall, and come out from their hibernating places in the spring. From the data to which he has access, it seems probable that in Maine the adults enter their winter hiding places early in October, and desert them in the spring as soon as the leaves of the alder are well expanded. Both in the fall and in the spring, the beetles feed freely on the foliage.

DESCRIPTION OF THE STAGES; MOLTING HABITS AND COLORATION.

THE EGG.

Description. Pale orange; ovate-oblong; average length 1.25 mm., average width 0.45 mm.; surface densely marked with fine pits. The egg is shown in figure 23.

Manner and place of deposition. Whenever it is possible, the eggs of this beetle are deposited within the larval tubes of *Acrobasis rubrifasciella* Packard, a leaf-rolling caterpillar of the family Pyralidae, which is often very common on the alders in Maine. The eggs are laid in the innermost part of the folded leaf, so that they are completely hidden and the leaf must be unrolled to expose them. Usually the eggs of *Altica* spp. are streaked with excrement by reason of an instinct which probably has arisen in connection with concealing them; occasionally the eggs of *A. bimarginata* are so streaked, but usually they are not, probably because, since the eggs are already so well protected, such an instinct is unnecessary and has been lost. In a few instances the writer has found the eggs deposited on the under side of a leaf; in such a case they were always placed next to one of the larger veins. In the laboratory, the beetles deposit eggs freely without any attempt at concealment. When first deposited, the eggs are soft and in color dark yellow, but they become bright orange as they harden, and by 24 hours they become the characteristic pale orange. Usually but not always the eggs turn dull gray 24 hours before they hatch.

The eggs are always deposited in clusters, never singly; a count of 90 clusters gave the following data (v stands for variant, or the number of eggs per cluster, and f for the frequency with which that variant occurred):

v	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
f	6	7	12	9	16	10	7	9	5	3	3	1	1	0	0	0	0	0	0	0	1

This shows 6 as the mean of the species, and gives 6.6 as the real average.

Hatching. Before the egg is ready to hatch, the shell becomes very brittle, and usually the egg turns grayish 24 hours previous to the emergence of the larva, although this is not always the case. Always, however, the lateral tubercles of the mesothorax and the metathorax show prominently through the egg shell as 4 black spots 20 hours before the egg is ready to hatch. When the larva is ready to emerge, it makes 2 longitudinal slits near, but not quite at, the anterior end of the egg. The only chitinized portions of the cuticula at the time of the emergence are the dorsal halves of the lateral tubercles of the last 2 thoracic segments, and the writer believes that they are the instruments used in rupturing the egg shell. These tubercles show up very prominently in a newly hatched larva, as the chitinized portions are jet black, while all the rest of the body is bright yellow. The explanation offered above would account for this peculiar appearance, which is characteristic of the newly hatched larvae of all of the Alticini which the writer has observed.

The thorax is arched out through one of these longitudinal slits, sometimes the right one, sometimes the left. The presence of the second slit doubtless lessens the rigidity of the egg shell, and makes it yield more readily to the efforts of the larva in the process of hatching. This is accomplished merely by the regular contraction and relaxation of the body muscles. The mesonotum is the first part to protrude through the opening, then the metanotum and the pronotum, giving the larva a sort of hunch-backed appearance. After a long, hard process of similar, slow, regular, alternate contraction and relaxation of the body muscles, the larva finally succeeds in withdrawing its head from the opening. In 5 minutes, or even less time, after the head is free, the legs are drawn out, all almost simultaneously, and the larva walks out of the shell.

This process was observed several times. The time required from the appearance of the first break in the shell until the larva was entirely free varied from 28 to 39 minutes; it usually occupied about 30. The following example is cited as a typical case: 10.05 first break in the egg shell; 10.10 second break in the egg shell; 10.20 metanotum and mesonotum exposed; 10.25 pronotum exposed; 10.31 head free; 10.33 prothoracic legs drawn out; the other legs freed almost simultaneously; 10.35 larva entirely out of the shell.

THE LARVA.

Description of the full grown larva. Head, thorax, and abdomen distinct; abdomen composed of 10 segments; pronotum and dorsum of 9th abdominal segment strongly chitinized to form the prothoracic and anal shields respectively; one pair of jointed legs borne by each of the thoracic segments; a single median anal proleg borne by the 10th abdominal segment. Length 1 cm.

Head directed obliquely downward and forward; strongly chitinized, shining black; the *epicranial suture,* at first extending cephalad along the mesal line, soon splits, passing back of the antenna to the base of the mandible on each side; it divides the head into three large segments, the median dorsal one the *postclypeus,* and the other two forming the *epicranium;* the *clypeus* is very narrow; *labrum* moderately large, rounded in front, shining black; *mandible* dark brown, moderate in size, with notched teeth at the apex; *trochantin* present at its base, non-chitinized; *maxilla,* with the cardo completely, the stipes incompletely, chitinized, bearing anteriorly a palifer with a 3-segmented conical palpus, and a very small nodule which probably represents the lacinia; *labium* with a large slightly chitinized basal piece, the fused mentum and submentum, bearing a ligula, unchitinized except at its base, from which arise a pair of small 2-segmented palpi; *antennae* inserted on the side of the head near the base of the mandibles, 3-jointed, white, the basal segment much larger than the middle segment, and the distal segment very small; *ocelli* wanting, the large sclerite between the labium and the prothorax (figure 18 B and C) is the *gula.*

Body wall of thoracic and abdominal segments brownish, densely beset with dull black cuticular nodules; prominent dull black dorsal, dorso-lateral, and lateral tubercles; ventro-lateral and ventral tubercles dull brown.

Abdominal segments 1 to 8 bear setiferous tubercles, segments 1 through 7 being identical; on the first 7, the setae are arranged in a mid-dorsal row of 2 tubercles on each segment (the anterior the larger), an upper and a lower row of dorso-lateral tubercles above the spiracle (each row composed of 2 small tubercles on each segment), a lateral row of prominent tubercles just below the spiracle (one tubercle to each segment), an upper and a lower row of ventro-lateral tubercles (a single tubercle each, on each segment), and a median ventral row (a single tubercle on each segment); on the 8th, the arrangement of the tubercles is the same except that the posterior of the mid-dorsals is the larger, and the upper and lower posterior dorso-lateral tubercles have united into a single one.

Abdominal segment 9 is modified dorsally into a strongly chitinized anal shield; ventrally it bears a large median tubercle, not clearly homologous with the other abdominal tubercles.

Abdominal segment 10 is very small; it has no setae nor tubercles, but bears ventrally the orange-yellow anal proleg (which probably represents the fusion of a pair of prolegs); the anal opening is shaped like an inverted Y, and lies in the middle of the proleg.

Metathorax and mesothorax. Mid-dorsal tubercles are present, homologous with those of the abdominal segments; they are broken along the mesal line (to provide a thin place where the cuticula can yield to strain, and split at the time of molting); of the dorso-lateral tubercles, the 2 posterior have fused into one, the upper anterior is non-setiferous, and the lower anterior has fused with the lateral tubercle; the mid-ventral tubercles are present and homologous with those of the abdominal segments; but no other homologies can be drawn.

Prothorax. Modified dorsally into a strongly chitinized cephalic shield; the mid-ventral tubercle is the only tubercle which the writer can homologize with those of the abdomen.

Spiracles. There are 9 pairs of spiracles, 8 abdominal and one thoracic; the abdominal spiracles are borne on little tubercles located just above the lateral tubercles on segments 1 to 8; the thoracic spiracle is borne on a tubercle just above the base of the mesothoracic leg; an homologous tubercle, present on the metathorax, shows no indication of a spiracular opening.

Legs. The legs are composed of 5 segments, with an anterior and a posterior sclerite externally, at the base; the anterior sclerite is setiferous in the prothorax, and non-setiferous in the mesothorax and the metathorax; the posterior sclerite is setiferous in all 3 thoracic segments; the proximal segment is incompletely chitinized ectad, and almost not at all entad; it fits closely into a socket formed by the infolded body wall, with which it is continuous; the second segment, which is chitinized proximally, is barely visible ectad, but is much larger entad; the third segment, strongly chitinized ectad, is about equal in size to the second segment; the strongly chitinized fourth segment is the longest of the leg segments; the short, strongly chitinized distal segment bears a single pulvillus and a single inward-curved claw. The setae are the same on all of the legs, except that the proximal segment of the prothoracic leg lacks the anterior seta borne on the ental surface of the mesothoracic and metathoracic legs. There is no homology between the segments of the larval legs and those of the imago.

Figures. The arrangement of the setae and tubercles of the full grown larva is shown in the following figures: dorsal aspect, figure 18 A (head, thorax, abdominal segments 1, 8, and 9); ventral aspect, figure 18 B (head, thorax, abdominal segments 1, 8, 9, and 10); lateral aspect, figure 18 C (head, thorax, abdominal segments 1, 8, 9. and 10). The structure of the larval legs is shown in the following figures: ectal aspect, figure 20 A; ental aspect, figure 20 B (both drawings were made from mesothoracic legs). The structure of the larval mouth parts is shown in the following figures: labrum, figure 19 A; mandible, figure 19 B; maxillae and labium, figure 19 C. A first instar larva is illustrated in figure 24; a second instar, in figure 25; and a third instar, in figure 26.

Color changes of the larva during growth. The body wall of these larvae is covered with minute cuticular nodules, which together with the tubercles, are the pigmented portions of the body. Just after hatching or immediately after a molt, the integument is translucent, and the larva appears bright orange yellow, as no pigment has yet been formed, and the yellow fat-body shows through. In a few hours pigment is formed in the tubercles and in the nodules. As the body wall is not stretched, the tubercles and the nodules lie very close together, and give the larva a dark aspect; late in the instar, the general color of the larva is much lighter, since the integument is stretched, the nodules farther apart, and the tubercles smaller in proportion to the body surface.

Such a series of color changes is very characteristic of all of the species of *Altica* which the writer has studied. They are either white or yellow after a molt (according to the color of the fat-body), as there is no pigment in the cuticula; they rapidly become darker, and the darkness is at a maximum a few hours after the molt; they become gradually lighter throughout the instar, and the coloration of the early and late part of the same instar is quite different in some species.

Description of the newly hatched larva. The coloration and setal arrangement (with the exceptions noted below) is the same in the newly hatched larva as it is in the mature larva; however the tubercles are proportionately much larger, and the cuticular nodules much closer together. The setae are distinctly capitate all through the first instar.

There are only 3 setae on the lateral tubercles of the mesothorax and the metathorax, instead of 4, as in the full-grown larva; and only 2 on the lateral abdominal tubercles instead of 3; and only one on the posterior dorso-lateral tubercles of the 8th abdominal segment instead of 2.

This condition is characteristic of the second instar larvae as well as those of the first instar; and not infrequently this same condition prevails in a full grown larva.

Head measurements of larvae.

1st instar.

Minimum	.38 mm.	
Maximum	.43 mm.	
Mean	.43 mm.	(21 specimens.)
Average	.42 mm.	(42 specimens.)

2nd instar.

Minimum	.64 mm.	
Maximum	.71 mm.	
Mean	.64 mm.	(5 specimens.)
Average	.67 mm.	(10 specimens.)

3rd instar.

Minimum	.86 mm.	
Maximum	1.05 mm.	
Mean	1.00 mm.	(29 specimens.)
Average	1.00 mm.	(81 specimens.)

Ratio of measurements: 1.6.
Theoretical measurements: .42; .67; 1.07.
Actual average measurements: .42; .67; 1.00.
Actual mean measurements: .43; .64; 1.00.

Coloration after hatching. When the larva hatches from the egg, it is entirely bright shining orange yellow, except for the lateral tubercles of the mesothorax and the metathorax, which show up very conspicuously in contrast to the rest of the larva, as 4 black dots. As has already been pointed out, there is no pigment in the cuticula except in these tubercles, and the general color of the fat-body shows through. It is a general rule in the coloration of *Altica* larvae of all species that those parts which are darkest in the fully colored larva, are the last to show signs of coloration in a recently molted specimen.

The coloration of the larva after it emerges from the egg is typically that outlined below: 20 min. abdomen darkish, head somewhat dull; 30 min. mesothorax and metathorax darkish above like the abdomen, head and pronotum still quite bright shining yellow; 45 min. head and pronotum blackish; 60 min. body all blackish and duller, lateral tubercles of the mesothorax and the metathorax less conspicuous; 75 min. body uniformly dull and darkish above, the tubercles darker than the body, and the head and legs darker than the tubercles; 90 min. no change; 120 min. head and legs darker, somewhat shining; 135 min. legs deep shining black, body decidedly dark, tubercles black but not shining, head and prothorax deep shining blackish yellow; 150 min. head and pronotum deep shining black. The lateral tubercles of the mesothorax and the metathorax continue darker than the others for about 24 hours.

Color description of a first instar larva, early.

Head, prothoracic and anal shields, and legs, shining black; general body color dark brownish black dorsally, somewhat lighter ventrally; dorsal and lateral tubercles black, not shining; ventral tubercles dark brown.

Color description of a first instar larva, late.

Head, prothoracic and anal shields, and legs, shining black; general body color dark golden yellow dorsally, lighter ventrally; dorsal and lateral tubercles dark brown; ventral tubercles golden yellow.

The molt to the second instar (first molt).

This molt is performed in exactly the same way as the molt to the third instar, and the process is described in detail under that heading. Numerous larvae were observed as they underwent the first molt; it required from 35 to 50 minutes to complete it.

Coloration after the first molt (second instar).

The coloration of the larva after the first molt does not differ from the coloration after the second molt, and is described in detail under the latter heading.

Color description of a second instar larva, early.

Head, prothoracic and anal shields, and legs, shining black; general body color brownish black dorsally, lighter ventrally; dorsal and lateral tubercles dull black; ventral tubercles but little darker than the body.

Color description of a second instar larva, late.

Head, prothoracic and anal shields, and legs shining black; general body color very dark golden brown dorsally, somewhat lighter ventrally; dorsal and lateral tubercles dark brown; ventral tubercles same color as the rest of the underparts.

The molt to the third instar (second molt). As is the case with arthropods in general, when the larva is ready to molt, a new cuticula is formed underneath the old one, and late in each instar, the old cuticula becomes very brittle. In the process of molting, it cracks first along the mid-dorsal line of the metathorax, the slit extending cephalad along the mid-dorsal line of the other thoracic segments, and the V-shaped epicranial suture of the head. During this time the larva is firmly attached to the leaf by the legs of the skin which is being shed, the tarsal claws of which are securely imbedded in the tissues, and by the anal proleg, which projects out a little beyond the old cuticula. By slowly and regularly contracting and relaxing the body muscles, the larva works its way out of the old skin; first the thorax is arched out and then the head is freed. The legs are drawn out almost immediately after the head, but as they are soft and weak, they are held closely appressed to the body, and the larva makes no attempt to walk for about half an hour. The insect is now attached to the leaf only by the anal proleg, and the old cuticula is left as a ring around 3 or 4 of the abdominal segments. This ring is finally pushed off over the anal proleg, mainly by the activities of the body muscles, although the legs are used a little at the end.

This molt was observed several times; a typical example is given below: 11.05 skin cracked along the metathorax; 11.15 head free; 11.17 legs free; 11.25 old cuticula left like a ring around the abdomen, which is about two-thirds free; 11.40 begins to walk; 12.05 entirely out of the old cuticula.

Coloration after the second molt (third instar). At the beginning of the molt, the larva, as it emerges from the old skin, is a pure orange yellow, except that the mandibles are reddish brown and the setal punctures dark. In about 20 minutes the setal punctures show up black, and the cuticular nodules are just beginning to be pigmented, although a hand-lens is necessary to observe this. In about 40 minutes the body has a general dullish cast, but the head, legs and prothoracic shield are still bright yellow. (The legs are always a paler and more translucent yellow than the rest of the body, probably because they contain less adipose tissue.) In about 50 minutes the distal segments of the legs have a dark cast.

The following figures refer to the time when the larva was fully free from the old cuticula, and the molt complete: 10 min. body and prothorax darkish, the tubercles not darker than the rest of the body, head still yellow, legs duller; 20 min. no change; 30 min. body not quite as dark as the prothoracic shield, distal segments of the legs blackish and the other segments dull, head somewhat dull; 40 min. body about the same color, head as dark as the body but not as dark as the prothoracic shield; 50 min. prothoracic shield blackish at the sides, head dull darker than the body, legs still light except the distal segments; 65 min. prothoracic shield dark brown; head, legs, and tubercles brown; general aspect of the body dark yellow brown; 95 min. little if any change; 110 min. head black, legs dark brown the distal segments black, prothoracic shield black, tubercles dark brown; 140 min. normal coloration;

Color description of a third instar larva, early.

Head, prothoracic and anal shields, and legs shining black; general body color very dark brown, almost black (aspect black dorsally and dark dull golden yelow ventrally); lateral and dorsal tubercles dull black; ventral tubercles brown.

Color description of a third instar larva, late.

Head, prothoracic and anal shields, and legs shining black; general body color very dark brown, almost black, dorsally, very dark golden yellow ventrally, much darker than earlier in the instar; dorsal and lateral tubercles black; ventral tubercles brown.

THE PREPUPA.

Formation of the pupal cell. In all insects which undergo a complete metamorphosis, the wings are developed internally in the larva, as hypodermal invaginations; then a part of this invagination evaginates, forming the wing-bud proper; just before the formation of the pupal cuticula, this wing-bud pushes out so as to lie outside the hypodermis; finally the pupal cuticula is secreted around it, and thus it is brought about that the internal wing-bud of the larva is external in the pupa. The period from the outpushing of the wing-bud in the larva until the molt to the pupa is spoken of as the prepupal period.

In the alder flea-beetle, the prepupal period is passed in the earth. As soon as the larva is fully fed, it enters the ground to complete its transformations. Sections of specimens fixed at this time show clearly that the entrance into the soil closely corresponds with the outpushing of the wing-buds.

In nature, as Lintner (1887) pointed out, the insects prefer to pupate under the mossy edge of a half-sunken rock, and the majority of the pupae are probably to be found in such situations. But even under natural conditions they will enter any fairly loose soil, pupating about an inch below the surface of the ground. The larvae construct a rude cell by contortions of the body, and the earth lining it is cemented together by a mucous secretion, probably poured out by the maxillary glands. (Labial glands, the ordinary salivary glands of insects, are entirely wanting in this species, as in Coleoptera generally.) The earlier prepupa is straight and can walk, but by the third day the body is strongly arcuate, and the insect is unable to move the legs. This is due to the degeneration of the larval muscles, for, as has been pointed out already, there is no relation between the larval legs and the imaginal legs. The latter are developed as knobs or pads at the bases of the larval legs, and do not project down into them, so that when the larva molts to the pupa, the larval legs are simply hollow shells.

Color changes of the prepupa. In several species of this genus, there is a distinct prepupal color cycle, the insect first becoming darker and then very much lighter in color. So far as the writer has observed, there is no change in the coloration of the prepupa of the alder flea-beetle.

THE PUPA.

The molt from the prepupa to the pupa. When the prepupa is ready to molt to the pupa, the larval cuticula cracks along the thorax as in an ordinary molt (beginning at the mid-dorsal line of the metathorax and extending forward) and the pupa gradually wriggles out by slowly contracting and relaxing the body muscles. The larval skin passes off over the caudal end of the body, where it may hang for several hours. At the beginning of the molt, each leg, though fully formed, is curled up into a little pad at the base of the larval leg, but as soon as they are free from the old cuticula they are straightened out so as to lie in the position normal to the pupa. The wings and elytra lie pushed ventrad beneath the old larval skin in about the same relations that they show in the pupa. The pupa is always formed with the ventral aspect uppermost, and it remains in this position throughout this period.

Description. The general appearance of the pupa is that typical of the chrysomelids: wings and elytra pushed ventrad; the femora extending away from the middle line, the tibiae toward it, and the tarsi caudad along the mesal line; the metathoracic legs passing under the wings; the antennae extending caudad, bent under the mesothoracic legs.

There are 9 abdominal segments (unless the anal plate may be counted as a vestigial 10th), the last bearing a pair of strong black caudal spines. The arrangement of the setae is that characteristic of the genus *Altica,* and does not present any specific characters. The only specific variation which the writer has noted in the pupal setae of the genus *Altica* is the number of setae present on the femora. Sometimes there are 3, and sometimes but 2. In *A. bimarginata* there are 3: a pair of pre-apical setae and one apical, on each femur.

Great variation prevails in the setae which may be present in any individual specimen. Any given seta may be wanting (though the writer has never found a pupa in which any of the head setae were absent), and certain extra setae are sometimes present on the thoracic segments. The greatest variation is to be found in the pygidial setae. Very rarely the caudal spines themselves may be wanting entirely. Where the setae are serially homologous, and the arrangement the same on both sides of the body, as on the abdomen, a seta missing on one segment is usually present on the others, and may be absent only on one side.

The setae occur only on the dorsal aspect of the body and serve to keep the insect from contact with the sides of the pupal cell, as it lies with the ventral aspect uppermost.

The average length of the pupa is 5 mm.; the average width is 2.5 mm.

When formed, the pupa is bright orange yellow, with the appendages a more translucent yellow; the setae are brown, and the caudal spines and the spiracles (which occur on the first 6 abdominal segments) black. Packard (1890) described the pupae as white, but this is without doubt a mistake. Lintner

(1887) corrected this statement, suggesting that Packard's description might have been made from an alcoholic specimen, or that just formed pupae might possibly be white. The context precludes the former explanation, and as has just been stated, the newly formed pupae, like the older ones, are yellow. Essig (1915) stated that the pupae are either white or yellow, but this statement is probably incorrect. The writer has spoken of this at length because *bimarginata* pupae may be distinguished from certain other *Altica* pupae which are white, by the color characters, which are very constant. As the pupae of *bimarginata* do become white in alcohol, this distinction is useful only in the case of living pupae.

Figure 27 shows the dorsal aspect of the pupa; figure 28, the ventral aspect; figure 21 A, the arrangement of the setae, dorsal aspect, (mesothorax, metathorax, abdominal segments 1 through 8); figure 21 B, the arrangement of the setae, ventral aspect; figure 21 C, the setae of the 8th abdominal segment and the pygidium; figure 21 D, the setae of the prothorax, dorsal aspect.

Color changes of the pupa. As has been stated, the pupa when formed is entirely bright orange yellow, except for the brown setae and the black caudal spines and the spiracles, which are also black. But as the pupa grows older, certain color changes appear, which are correlated with the internal metamorphosis, and furnish a good indication as to the age of the pupa. All other species of the Alticini and the Galerucini which the writer has studied show similar external evidences of the progress of the internal metamorphosis by the formation of pigment in the cuticula.

The first change is to be noticed in the eyes, which become light brown on the 4th or 5th day after the pupal molt. On the 7th day, as a rule, the eyes are dark brown, the wings light gray, and the tips of the mandibles red brown. On the 8th day, the eyes are black, the distal tarsal segments black, and the femoro-tibial joints black; the labrum, the tips of the mandibles, and the palpi are brown; and there are brown spots on the pronotum. On the last day of pupal life, in addition to these markings, the coxae and tibiae are black, and the head is brown between the eyes.

There is of course a considerable amount of individual variation as to the time required for the appearance of these changes, even in pupae which have come from the same egg cluster, but the sequence of the changes and the pigmentations themselves take place very constantly.

The elytra do not become pigmented at all during the pupal period, although the true wings become dark gray or almost black; since the wings lie under the elytra, the latter appear as if they were colored gray, but if one lifts them up, it is clearly seen that they are uncolored.

Another point which should be noted is the fact that no pigment is deposited in the pupal cuticula. The imaginal cuticula begins to be formed on the 3rd or 4th day of pupal life, and all of the pigment is formed in this cuticula. The pigmented imaginal cuticula shows up very plainly inside of the sheaths of pupal cuticula which enclose them. The imaginal mouth-parts are not completely formed at the molt to the pupa, and the pupal sheaths are much larger than the organs developed within them.

THE ADULT.

Description.

"Oblong, subparallel, above blue or slightly bronzed, usually moderately shining, sometimes subopaque. *Antennae*[1] half as long as the body, piceous, joints 2-3-4 gradually increasing in length. *Head* feebly shining, frontal carina obtuse, tubercles usually well marked, a few punctures extending across the head above the tubercles and near the eyes. *Thorax* one-half wider than long, slightly narrower in front, sides feebly arcuate, the margin very narrow, disc moderately convex, the ante-basal transverse depression rather deep, slightly sinuous at the middle, reaching the sides and joining the marginal depression, surface distinctly alutaceous, sparsely punctulate, punctures more distinct near the apex and the front angles. *Elytra* distinctly wider at the base than the thorax, humeri distinct, umbone moderately prominent and with a slight depression within it, a prominent lateral plica begins at the umbone, extends parallel with the margin, curves toward the suture near the apex, surface alutaceous, the punctures fine and indistinct, not closely placed. *Body beneath* and *legs* blue black, shining, abdomen sparsely and indistinctly punctate. Length .20-.24 inches; 5-6 mm."

The above description is copied directly from Horn (1889).

The Maine forms are usually bright cobalt blue, but rarely they may be a greenish blue. The writer has never seen any bronzy or subopaque forms in the state. The lateral plica varies in prominence, but in all specimens which the writer has examined, it has been plainly in evidence.

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[1] The italics are the writer's; there are no italicized words in Horn's description.

Emergence of the adult. The pupa is as deeply pigmented as it will ever be about 12 hours before the emergence of the adult. The coloration has already been described on page 266.

About half an hour before the emergence, the mouth-parts are moved continually. The pupal cuticula first splits along the mid-dorsal line of the mesothorax; then this crack extends backward down the mid-dorsal line of the metathorax, and forward along that of the prothorax. This split is made by the scutellum, which is moved up and down until the cuticula is ruptured. Within 20 or 30 minutes after the crack has appeared, the head and mouth-parts, as well as the whole pronotum, have been freed from the pupal cuticula. The elytra and wings, which have increased to their full length, have been pushed nearly dorsad. The prothoracic legs project out on each side, strongly bent at the femoro-tibial joint; the mesothoracic legs extend straight down the body, as do also the metathoracic pair, which have been drawn from under the elytra. The antennae lie straight down the middle of the ventral aspect, slightly bent in at their tpis, but entirely free from the legs. The abdominal muscles contract and expand rhythmically.

After the mouth parts have been freed, the beetles usually rest about 5 minutes, but soon recommence the task of molting. The next step is to withdraw one of the prothoracic legs from its pupal sheath, the other following almost immediately. At this point the antennae usually are drawn out: the head is inclined ventrally as far as possible, and then is suddenly thrown backward dorsally as far as is possible, and thus the antennae are pulled out of their pupal cases. Kicking and pushing with the tibio-tarsal joints of the front legs, the beetle rapidly succeeds in drawing out the mesothoracic legs and then the metathoracic legs from their pupal sheaths. The movements of the abdomen have pushed the pupal cuticula farther and farther caudad on the dorsal aspect of the body, and on the wings and elytra, so that by this time they are two-thirds free from the cuticula. The wings and elytra lie entirely dorsad. The pupal skin is now pushed downward and backward off the tip of the abdomen; the tibio-tarsal joints of all of the legs are used in this process which requires only a short time for its accomplishment.

The pupa is formed with the ventral aspect uppermost, and the adult remains on its back for about 4 hours after it has emerged. The beetle is of course very soft, and remains in the pupal cell, until it is fully hardened and colored, which requires about 24 hours.

The coloration of the adult. The beetle which has just emerged is quite as yellow as was the pupa. The eyes, antennae, and mandibles (sometimes also the labrum) are black, the elytra are grayish orange, and the wings gray. The insect becomes colored gradually, but it is some 20 hours before the characteristic coloration is reached. The beetle is entirely blackish above within 5 hours, and the underparts do not begin to color up at all until after that time. The centers of coloration are the pronotum, the ventral aspect of the pygidium, the bases of the elytra, the bases of the coxae, and the femoro-tibial joints of the legs.

THE RANGE OF FOOD PLANTS.

In nature, the alder flea-beetle is confined almost entirely to the leaves of the alder, at least in Maine, and the only other plant on which the writer has taken them is the willow *(Salix rostrata* Richards.)

There is a biological race of this species which occurs on balsam poplar, in Veazie, Maine. Eggs, larvae, pupae, and adults are indistinguishable from the typical *bimarginata*, and the larvae and adults eat alder or willow as readily as they do balsam poplar. The forms taken on alder however (both larvae and adults) have been tested many times on the leaves of the balsam poplar, but the results have always been negative. This is not surprising, when individuals which had already eaten alder were concerned, for the glandular leaves of the balsam poplar have a very decided taste and smell, but just hatched larvae of the alder race which had never tasted any food were equally emphatic in their refusal to subsist on the balsam poplar. Both larvae and adults will feed freely on the leaves of willow; they ate the foliage of all species with which they were tested.

Nevertheless the writer feels very sure that these are only biological races of the same species, if they deserve even that distinction. The habits, size, appearance, and life-history of the variety on the balsam poplar are exactly the same as that described for the alder forms, save that the eggs are deposited in clusters on the under side of the leaves. Specimens were referred to Mr. C. W. Leng of New York City, who kindly determined them as undoubtedly *Altica bimarginata* Say.

All of the data on pages 253-270 appertain to the alder race.

Gibson (1913 p. 6) recorded this species as feeding on alder, willow, and poplar. Essig (1915 p. 266) reported this insect from alder, willow, poplar, and cottonwood.

The following tables record a few food plant tests which were made with the larvae and adults of the 2 races. The tests were made as follows: 6 larvae or adults were kept in a clean shell-vial without food for 24 hours; then an uninjured leaf of the plant to be tested was introduced, and the insects were left undisturbed for a second 24 hours; at the end of that time the leaves were examined, and a record made as to whether they had been considerably eaten, slightly eaten, or left untouched.

Altica bimarginata. (Alder race.) Food-plants of adult.

(i) Eaten readily.
  Willow, *Salix* sp. near *nigra* Marsh, *S. cordata* Muhl., *S. rostrata* Richards; alder, *Alnus incana* (L.) Moench.
(ii) Eaten slightly.
  European gooseberry, *Ribes Grossularia* L.
(iii) Refused.
  Balsam poplar, *Populus balsamifera* L.; gray birch, *Betula populifolia* Marsh; white elm, *Ulmus americana* L.; cultivated rose, *Rosa* sp.; wild red cherry, *Prunus pennsylvanica* L. f.

Altica bimarginata. (Poplar race.) Food-plants of adult.

(i) Eaten readily.
  Willow, *Salix cordata* Muhl.; balsam poplar, *Populus balsamifera* L.; alder, *Alnus incana* (L.) Moench.
(ii) Eaten slightly.
  White elm, *Ulmus americana* L.
(iii) Refused.
  Gray birch, *Betula populifolia* Marsh; wild red cherry, *Prunus pennsylvanica* L. f.; red osier dogwood, *Cornus stolonifera* Michx.

Altica bimarginata. (Alder race.) Food-plants of larva.

(i) Eaten readily.
  Willow, *Salix* sp. near *nigra* Marsh. *S. cordata* Muhl.; aspen pop-
  Richards; alder, *Alnus incana* (L.) Moench.
(ii) Refused.
  Balsam poplar, *Populus balsamifera* L.; wild strawberry, *Fragaria virginiana* Duchesne; red osier dogwood, *Cornus stolonifera* Michx.

Altica bimarginata. (Poplar race.) Food-plants of larva.

(i) Eaten readily.

Willow, *Salix* sp. near *nigra* Marsh, *S. cordata* Muhl.; aspen poplar, *Populus tremuloides* L.; balsam poplar, *Populus balsamifera* L.; alder, *Alnus incana* (L.) Moench.

The form of the scientific names and the sequence of the plant families in the above tables follows the use of the last edition of Gray's Manual.

The writer has found the following references to additional host-plants in the literature:

Alder. *Alnus serrulata* Willd. [Now classed as *rugosa* (DuRoi) Spreng.]
Harris (1869); Lintner (1887); Packard (1890).
Knotweed and smartweed. Blatchley (1910).

ACTIVITIES OF THE ALDER FLEA-BEETLE.

Feeding Habits of the Larva.

The larvae live exposed on the leaves of their food-plants, on either surface. In the case of the alder, when they first hatch they crawl to the petiole end of the leaf, where they feed for a few days protected under the slightly revolute margin. At first the larvae eat only the lower epidermis and the green tissue, leaving the upper epidermis; but before this instar is over, they eat this epidermis also, leaving only a skeleton of the larger veins. This perfect and beautiful skeletonization, which has also been remarked upon by Harris (1869), Lintner (1887), and Packard (1890) is characteristic of all of the larval feeding, with the exceptions here noted; it is illustrated in figure 29. The nearly full grown larva eats holes through the leaves, as does the adult. The skeletonization is not as perfect on the leaves of the balsam poplar or the willow, as it is in the case of the larva. A balsam poplar leaf skeletonized by the larvae of *Altica bimarginata* is shown in figure 31.

The Feeding Habits of the Adult.

The adult beetles feed very freely on the leaves of the alder, eating little holes through them. This method of feeding, which is as characteristic as that of the larvae, is illustrated in figure 30. The adults feed both in the fall and in the spring. Willow and balsam poplar are attacked in the same way, and in no case do the adults ever skeletonize the leaves.

COPULATION.

The male and female remain in copulation several hours. The writer has never observed them to pair more than once, but it is probable that they do, since this is quite characteristic of related species.

NUMBER OF EGGS DEPOSITED BY A SINGLE FEMALE.

The writer has very little data as to the number of eggs which one female may deposit. None of the females which he has isolated after pairing deposited more than 35 eggs. But related species may deposit as high as 500 eggs per female, and doubtless 35 is far too low even to approximate the number of eggs which one female *bimarginata* can deposit. They usually begin to oviposit within a few days after pairing.

NATURAL ENEMIES.

FUNGOUS ENEMIES.

Both in the laboratory and in the field, larvae, prepupae, pupae, and adults are very susceptible to the attacks of *Sporotrichum globuliferum* Speng. if the conditions are right for infection. The writer does not doubt that this fungus played an important part in checking the outbreak of the alder flea-beetle, since it was abundant both in 1914 and 1915. While probably the fungus was not the only agent in the extermination of this species, nevertheless the extreme abundance of these insects offered ideal conditions for fungus to work, and doubtless great numbers of *Altica bimarginata* were destroyed in this way. Dr. Roland Thaxter of Harvard University kindly determined the species of fungus for the writer.

The pupae are quite subject to a wilt-disease, probably bacterial in its nature, but the writer has made no attempt to isolate the causative organism.

INSECT PARASITES.

An interesting parasite was bred from the adult beetles in the summer of 1915, a dipterous insect of the family Tachinidae, which was determined by Mr. C. W. Johnson of the Boston

Museum of Natural History as *Hyalomyodes triangularis* Loew. It was described under the generic name of *Hyalomyia* by Loew (1863, p. 85), and described again as a new species by Townsend (1893, p. 429), as *Hyalomyodes weedi*. The identity of the types was established by Coquillet (1897, p. 70), but he recognized *Hyalomyodes* as a distinct genus from *Hyalomyia*, and therefore the correct name stands as *Hyalomyodes triangularis* Loew.

The larvae are internal parasites of the adult beetles. The writer has no data as to the length of larval life, nor the manner of oviposition, but it seems probable that the eggs are deposited on the adult beetles in the spring or summer, after they have come out from hibernation. When the larva is full grown, it issues from the beetle, forcing its way out through the dorsal side of the abdomen, between the last two abdominal segments. The larva is white, with irregular brown splotches. In a few hours a brown puparium is formed, and the adult fly emerges about 2 weeks later.

1 puparium formed July 9, 1915; adult emerged July 21................12 days.
1 puparium formed July 21, 1915; adult emerged Aug. 9................19 days.
2 puparia formed July 26, 1915; adults emerged Aug. 9................14 days.

The writer has not found any reference to the life-history of this species in the literature. *Celatoria spinosa* Coquillet, a related species which the writer has bred from the adults of 2 species of *Altica*, has been recorded by Coquillet (1890, p. 235) as bred from the adults of *Diabrotica soror* LeC.

CONTROL.

The writer has had no occasion to work on the control of these insects, but there is no reason to suppose that the measures employed in combating other flea-beetles would not serve to keep the alder flea-beetle in check, wherever their application was practicable. A thorough spraying with arsenate of lead at the rate of 3 pounds (paste form) to 50 gallons of water, as soon as the beetles appear in the spring, and repeated in late June and mid-July for the larvae, if necessary, would doubtless control this species.

THE SYNONYMY OF THE GENUS *ALTICA* GEOFFROY.

Altica Geoffroy 1762. Hist. nat. des. ins. t. 1, p. 244.
  Haltica Illiger 1802. (Emend.) Mag. f. Insektenk. Bd. 1:138.
  **Haltica* Hoffman 1803. (Emend.) Ent. Hefte.
  **Graptodera* Chevrolat 1834. Cat. Dejean. ed. 2.

The systematic position of the flea-beetles was a matter of great dispute for about 50 years after Geoffroy had proposed the genus *Altica* to include them. A summary of the usages of the various writers from the 10th edition of Linnaeus' "Systema naturae" in 1758, which has been adopted as the arbitrary starting point for zoological nomenclature, to the final establishment of *"Haltica"* as a definite genus by Illiger in 1807, is given in the 2 tables published below. A more complete account of this history may be found in Kutschera (1859), Allard (1860), and Chapius (1875).

Authors who retained *Altica* previous to 1807.

*1762 Geoffroy p. 244; 1764 Geoffroy p. 244; 1775 De Geer p. 290; 1775 Fabricius p. 112; *1785 Fourcroy; 1789 Olivier p. 128; 1790 Olivier p. 100; 1796 Latreille p. 63; 1802 Illiger p. 138 *(Haltica)*; *1803 Hoffman; 1804 Latreille p. 323; 1807 Latreille p. 63; 1807 Illiger p. 81 *(Haltica)*.

Authors not retaining *Altica* previous to 1807.[2]

1758 Linnaeus p. 373 *Chrysomela* (Saltatoriae femoribus posticis crassisimis); 1763 Scopoli p. 69 *Chrysomela* (Saltatoriae); 1776 Fabricius p. 32 *Chrysomela* (Altica similis Chrysomelae saltatoriae Linn. certe huius generis); 1781 Fabricius p. 131 *Chrysomela* (Alticae saltatoriae femoribus posticis incrassatis); 1787 Fabricius p. 75 *Chrysomela* (Alticae saltatoriae femoribus posticis incrassatis); 1788 Linnaeus p. 1691 *Chrysomela* (Saltatoriae femoribus posterioribus incrassatis: Alticae); 1792 Fabricius t. 1, pt. 2, p. 24 *Galeruca* (Saltatoriae); 1801 Fabricius t. 1, p. 417 *Colaspis* (Saltatoriae), t. 1 p. 445 *Chrysomela* (Saltatoriae), t. 1 p. 463 *Crioceris* (Saltatoriae), t. 1 p. 477 Lema (Saltatoriae), t. 1 p. 491 *Galleruca*[3] (Saltatoriae femoribus posticis incrassastis); t. 1 p. 502 *Cyphon* (Saltatorii); t. 2 p. 57 *Cryptocephalus* (Femoribus saltatoriis).

Altica was proposed by Geoffroy in 1762 as a distinct genus to include the jumping chrysomelids which had been included by Linnaeus (1758) in the genus *Chrysomela*. The originai definition of *Altica* was "Antennae ubique aequales, femur a postica crassa subglobosa" (p. 244), and as first constituted the genus included 19 species. In modern usage, as one would expect, the genus *Altica* is defined within much narrower limits, and the original genus has been split up into many smaller ones, so that *Altica* as we regard it today includes only a small portion of the species agreeing with Geoffroy's original description, which quite closely approximates our present conception of the tribe Alticini.

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*The writer has not had access to this paper.

[2] The flea beetles are grouped at the end of the respective genera in which they are placed with the designation "saltatoriae" or some similar expression, as is indicated in the parentheses.

[3] The older authors spelled this word sometimes with one "l" and sometimes with 2. The genus was constituted by Geoffroy (1762) as *Galeruca* (p. 251), which is therefore the correct form. In this section of the paper the writer has indicated the spelling as it is to be found in the various papers quoted.

Geoffroy's (1762) discussion of the alticines is very interesting, and a translation, as literal as possible, follows: "To jump actively in the air with the agility of fleas is one of the peculiarities of the insects of this genus, a character which has given them the Latin name of *Altica*, or in French sauteurs, in place of the name Mordelles under which they have been described by some recent writers. We have reserved this latter name for some insects which constitute a different genus from this, although the two have been confused.

"To accomplish this active and considerable jump, nature has made the hind legs of the altise larger and stronger than the others. Especially the femora of these legs are remarkable. In almost all of these insects they are disproportionately large and often almost spherical, a character which makes them walk badly and slowly; but these great femora also enclose sufficiently strong muscles to execute such a violent movement as that which these animals make in leaping. We have drawn the character of the genus from the large femora and from the form of the atnennae which are quite long and of the same diameter throughout. The altises are all quite small. They are found in great quantities on potherbs, especially in the spring. They riddle and consume them. I have also found on these same plants numbers of small larvae, which may well be those of these altises, a thing which I do not dare affirm as I have not followed their metamorphoses."

There are 3 points which should be noted in conection with the paragraphs just quoted. First, the date which is usually assigned for the erection of the genus *Altica* is 1764; however, this is an error. The original date of publication of the Histoire d'insects by Geoffroy was in 1762, and the 1764 edition was a reprint. (The writer has had access only to the latter edition, and the page references given in this paper all refer to that printing, but as all of the page references to the 1762 edition agree with the pages as here given, it is probable that the pagination of the 2 is identical; such also is the inference one would draw from Hagen's Bibliotheca Entomologica.)

In the second place, Geoffroy proposed *Altica* to take the place of *Mordella* Linnaeus (p. 244). But Geoffroy was mistaken in stating that Linnaeus placed the flea-beetles in the genus *Mordella*. In the 1758 edition of the Systema naturae which has been constituted the standard from which binomial nomenclature dates, the flea-beetles were put in the genus *Chrysomela* with the designation "Saltatoriae femoribus posticis crassissimis" (p. 373). Each species under this heading is described as "Mordella etc." and it is possibly this fact that accounts for Geoffroy's statement, but more probably it is because in the 1756 edition the flea-beetles are evidently included under *Mordella,* which is characterized as "Antennae filiformes, ultimo globoso. Pedes saepe saltatorii". But in 1758 and all of the later editions *Mordella* is used by Linnaeus for Coleoptera very distinct from the flea-beetles.

Finally, Geoffroy was also mistaken in saying that *Altica* was derived from the Latin. It is really derived from a Greek word, ἅλτικος, a leaper. As in Greek "h" is not a letter but is represented only by an asper, this omission of the "h" was a not unnatural error.

Illiger (1802) pointed out the proper derivation and corrected the speling. In his list of insect genera, we find: "Haltica-ae f Flohkäfer. ἅλτικος, zum Springen geschikkt. Nicht Altica." (p. 138). But this emendation cannot stand, for by Article 19 of the International Code: "The original orthography of a name is to be preserved unless an error of transcription, a lapsus calami, or a typographical error is evident" we must return to the first spelling, *Altica.* Hoffman (1803) also emended the spelling to *Haltica,* apparently independently (Chapius 1875, p. 16: the writer has not had access to Hoffman's paper). In this connection it is interesting to note the opinion of Allard (1860) who wrote long before the Code was drawn up: "It seems to me that the orthography of the word should be determined by priority, and since Geoffroy in 1762 and Fourcroy in 1785 wrote it with an 'A', with Latreille we must respect their right of invention and omit the 'H' " (p. 41).

It is unfortunate that it is necessary to make any change in the name of a genus so important, so well-known, and so firmly established as *"Haltica",* but the change is such a slight one that there should but little confusion result. It is obvious that all of the larger groups of which *Altica* is the type genus must be changed in a corresponding fashion, Halticini to Alticini, Halticae to Alticae etc.

The English and German authors as a whole adopted the emended spelling as soon as it was proposed. The French however clung to the old spelling for many years. *"Haltica"* is the spelling universally recognized today; the last systematic paper in which the writer has found the old spelling is Allard (1860). The word is probably spelled with an "A" in Allard (1867), a publication to which the writer has not had access.

Chevrolat (1834) proposed the genus *Graptodera* as a substitute for *Altica* Geoffroy, omitting this genus entirely. (The writer has not had access to this paper: authority for statement Chapius 1875, p. 60.) This usage was followed by Allard and several writers. But Chapius (1875) pointed out the convenience of the term "Halticides" and the consequent necessity of preserving a genus *"Haltica"*. Kutshcera (1859), Fairmaire (1856) and Redtenbacher (1849) all retained *"Haltica"*. Since Chapius' work, it is fair to state that *Graptodera* Chevrol. has been reduced to the synonymy, and that *"Haltica"* has been recognized as a valid genus. The use of Illiger (1802) has been universally followed in the spelling, but this practice is inadmissible, and we must return to Geoffroy's original orthography, *Altica*.

The writer is not in a position to discuss the proper systematic position of the genus *Altica,* nor the proper rank to which its group should be assigned, but a brief summary of the development of the Alticini as a tribe (or according to some writers as a family) may not be without interest. A full discusion may be found in Kutschera (1859) and Chapius (1875).

The first attempt to divide the chrysomelids into groups seems to have been made by DeGeer (1775), who divided them into 4 families, *Altica* being the sole representative of the 4th family (p. 289). Latreille (1796) grouped various chrysomelid genera together as his 24th family (p. 63). Later (1804) he called this family the Chrysomelinae (t. 11, p. 323) and placed the genus *Altica* in it (t. 12, p. 5). In his next publication (1807) he recognized the same classification (p. 42 and p. 63). In 1810, he divided this family into the Criocerides (p. 232) and the Chrysomelinae (p. 235), retaining *Altica* under the latter (p. 235). This same plan was followed in 1817[1], but in 1825[1] he changed these names to Eupodes and Cycliques respectively. In 1830[1] he subdivided the Cycliques into 3 groups, Cassidaires, Chrysomelines, and Gallerucites, the last being further subdivided into the Gallerucites isopodes with *Galleruca* as the type, and the Gallerucites anisopodes with *Altica* as the type.

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[1] The writer has not had access to this publication; authority for statement Kutschera (1859), p. 10–11.

Chapius (1875) recognized the Galerucides as a tribe, which he divided into 2 subtribes, the Galerucides proper and the Halticides. The latter he subdivided into 19 groups. Le Conte and Horn (1883) followed this use, recognizing the Galerucini as a tribe of the Crysomelidae, and dividing it into the subtribes Galerucini and Halticini. Horn (1889) has published the only monograph of the American Halticini (properly to be called Alticini). He found 14 of Chapius' 19 groups in America, and subdivided 3 of them into 2 groups each, so that he listed 17 groups of American Alticini. One of these groups which he subdivided was the "Halticae" of Chapius, which became the Disonychae and "Halticae" (represented in this country by the single genus *Altica)* of Horn.

Some recent authors have constituted the Alticidae as a separate family, but it seems best to the writer at least for the present either to regard the Alticini as a tribe under the family Chrysomelidae, or to follow the use of Horn and regard it as a subtribe of the tribe Galerucini.

The following characterization of the group Alticae and the genus *Altica* is copied directly from Horn's monograph (1889):

Alticae. "Antennae 11-jointed. Thorax regularly arcuate at the base, with a distinct ante-basal line variable in distinctness, not limited at the extremeties by a longitudinal plica. Posterior tibiae with, at most, a very slight sulcus on the posterior edge near the apex. Anterior coxal cavities open behind. Claw joint of posterior tarsi slender, claws appendiculate."

Altica. "Head short, usually deeply inserted, front regularly declivious, the interocular carina never prominent, the tubercles usually feebly masked. Anntenae half as long as the body, joints 2-3-4 gradually longer, except in *rufa.* Labrum small. Maxillary papli short, rather stout, the terminal joint short and conical. Thorax usually one-half wider than long and broadest at base, and with a more or less distinct ante-basal impressed line, base arcuate, lateral margin more or less thickened at the front angles. Elytra usually a little wider at the base than the thorax, the punctation of surface confused. Prosternum rather narrow between the coxae, the coxal cavities open behind, angulate externally. Legs moderately long, tibiae of posterior legs not or feebly sulcate, terminated by a small spur. Tarsi moderate in length, claws with a broad dilatation at the base."

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1860. Essai monographique sur les galerucites anisopodes (Latr.) ou description des altises d'Europe. Ann. Soc. ent. Fr. 1860. ser. 3, t. 8: 39–144, 369–418, 539–578, and 785–834.

[1]1867. Monographie des alticides. L'Abeille. 1866–67. t. 3:169. (Ref. Chapius 1875 p. 16).

Blatchley, Willis Stanley.

[2]1910. An illustrated catalog of the Coleoptera or beetles...... known to occur in Indiana..........(p. 1201).

Briton, Wilton Everett.

[2]1911. Vacation notes in the Adirondacks. Jour Ec. Ent. v. 4:544.

Bruner, Lawrence.

[2]1893. Insect enemies of ornamental and shade trees. Ann. Rpt. Neb. Hort. Soc. 1893, p. 166–235 *(alni,* p 205–206, fig. 46).

Chapius, F.

1875. Histoire naturelles des insectes. Genera des Coleopteres. t. 11.

Chevrolat, Pierre Francois Marie Auguste, Comte.

[1]1834. *In* Dejean, Catalogue des Coleopteres, ed. 2. (Ref. Agassiz, Nomenclator zoölogicus. Chapius 1875, p. 61 and Kutschera 1859, p. 11, give this date as 1837).

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1890. The dipterous parasite of *Diabrotica soror.* Insect Life v. 2:233–236.

1897. Revision of the Tachinidae of America north of Mexico. U. S. Bur. Ent. Tech. Bul. 7. (p. 70).

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Essig, E. O.

[2]1915. Injurious and beneficial insects of California. p. 264–266.

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[1] Writer has not had access to this paper: reference unverified.

[2] This paper deals directly with *Altica bimarginata* Say.

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1776. Genera insectorum.
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1787. Mantissa insectorum.
1792. Entomologia systematica......
1801. Systema eleutheratorum.

Fairmaire, Leon.

[1]1856. Genera des Coleopteres d'Europe. (Ref. Chapius 1875 p. 60).

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[2]1905. Insects affecting park and woodland trees. (v. 2, p. 573).

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[1]1859. Les alticides. Ann. soc. Linn. Lyon. 1859. ser. 2, t. 6: 157–384.

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[1]1785. Entomologia parisiensis......

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[1]1762. Histoire abregee des insectes......
1764. Histoire abregee des insectes......, ed. 2.

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[2]1913. Flea-beetles and their control. Can. Dept. Agr. Ent. cir. 2 p. 6.

Harris, Thaddeus William.

[2]1869. The entomological corespondence of Thaddeus William Harris. Edited by Samuel Hubbard Scudder. Occ. papers Bos. Soc. Nat. Hist. I (*alni,* p. 267–268).

Hoffman, J. J. and others.

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Horn, George Henry.

[2]1889. A synopsis of the Halticini of Boreal America. Trans. Am. Ent. Soc. 1889. v. 16:163–320.

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1807. Verzeichniss der Arten der Flohkäfer. Halticae. Mag. f. Insektenk. 1807. Bd. 6:81–182.

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[2]1912. Insect Notes for 1912. Me. Agr. Exp. Sta. Bul. 207. (p. 459–460).

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Latreille, Pierre Andre.

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1804. Histoire naturelle.......... des crustaces et des insectes. t. 11.

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1810. Considerations generales sur l'ordre naturel des animaux..........

[1]1817. Le regne animal. (Ref. Kutschera 1859, p. 10).

[1]1825. Familes naturelles. (Ref. Kutschera 1859, p. 10).

[1]1830. Le regne animal. ed 2. (Ref. Kutschera 1859, p. 11).

LeConte, John Lawrence.

[2]1857. Report of the Exploration and Surveys...... for a Railroad from the Mississippi River to the Pacific Ocean. v. 12. Report on the insects collected, p. 1–72, pl. 1–2. *(prasina,* p. 24, p. 67; *plicipennis,* p. 24.)

[2]1859. The Coleoptera of Kansas and Eastern New Mexico. *(ambiens,* p. 25; *subplicata,* p. 25).

[2]1860. Notes on Coleoptera....... Proc. Acad. Nat. Sci. Phila. v. 12:315–321. (p. 317).

LeConte, John Lawrence, and Horn, George Henry.

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1756. Systema naturae........ ed. 9.
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1788. Systema naturae........ ed. 13.

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[2]1888. Fourth report on the injurious and other insects of the State of New York. p. 1–237. (p. 96–101).

Loew, Hermann.

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Lugger, Otto.

[2]1899. Beetles........injurious to plants. Minn. Agr. Exp. Sta. Bul. 66. (p. 241).

Mannerheim, Carl Gustav von.

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Packard, Alpheus Spring.

[2]1890. Insects injurious to forests. Fifth Rpt. U. S. Ent. Comm. (p. 630–632, fig. 208).

Redtenbacher, Ludwig.

[1]1849. Fauna austriaca. Die Kafer nach der analytischen Methods bearbeitet.

Say, Thomas.

[2]1824. Descriptions of coleopterous insects..... Journ. Acad. Nat. Sci. Phila. v. 4: ....– . (p. 85).

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1763. Entomologica carniolica........

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[1,2]1843. Catalog der Käfersammlung von J. Sturm. *(carinata,* p. 282).

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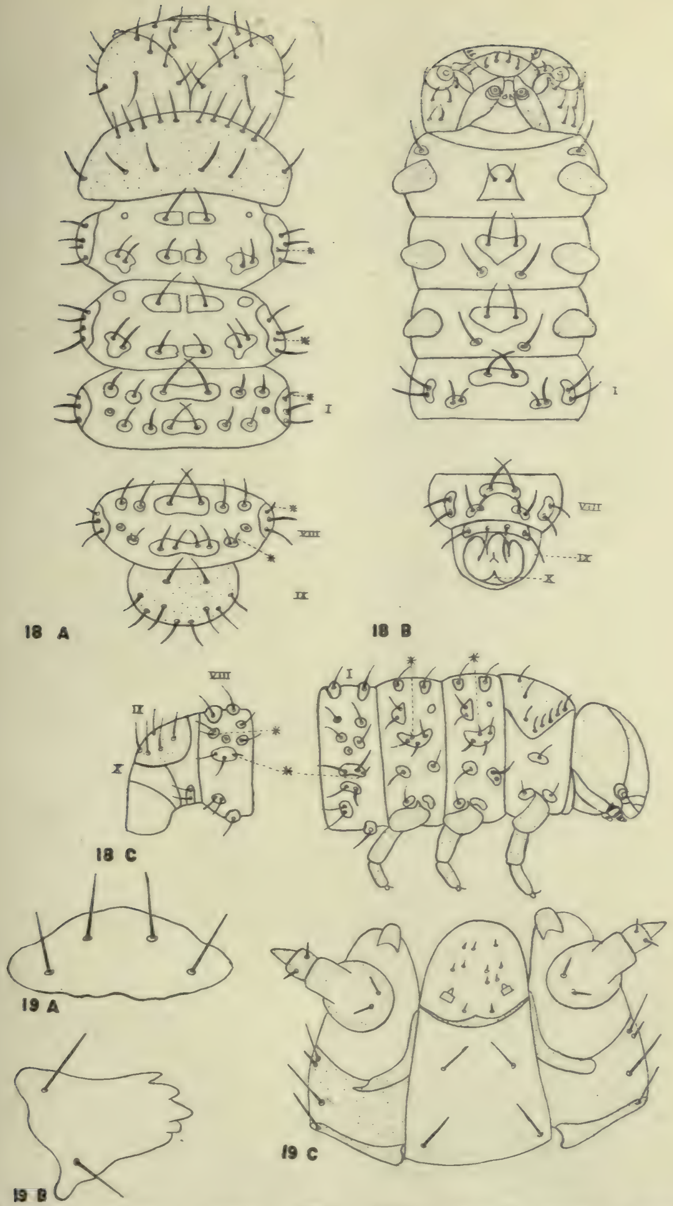
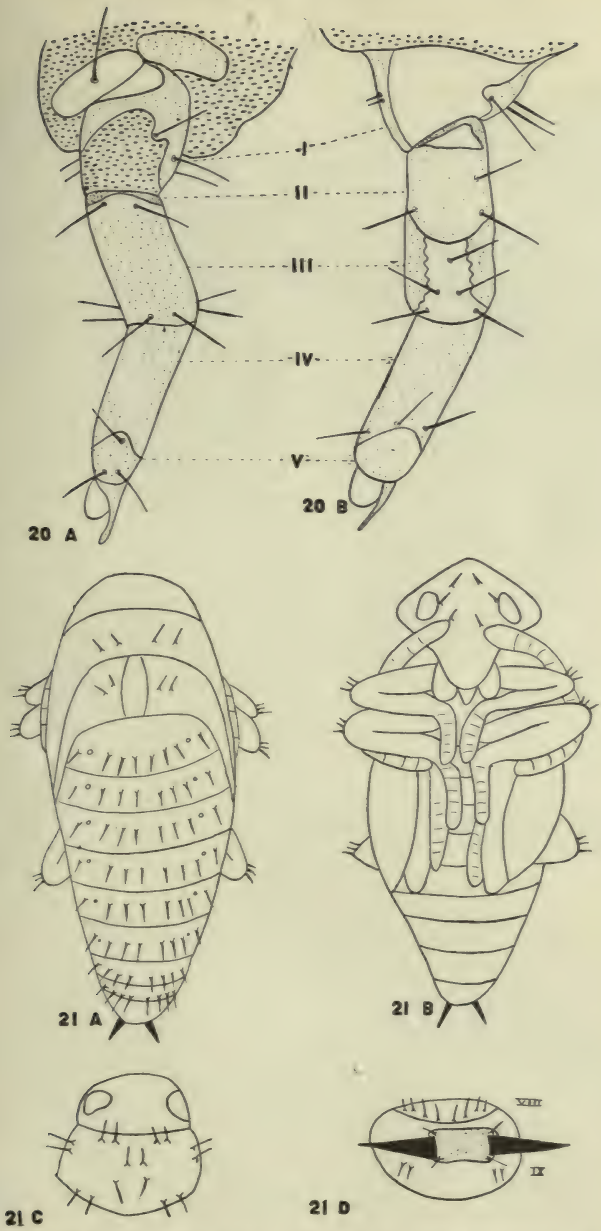
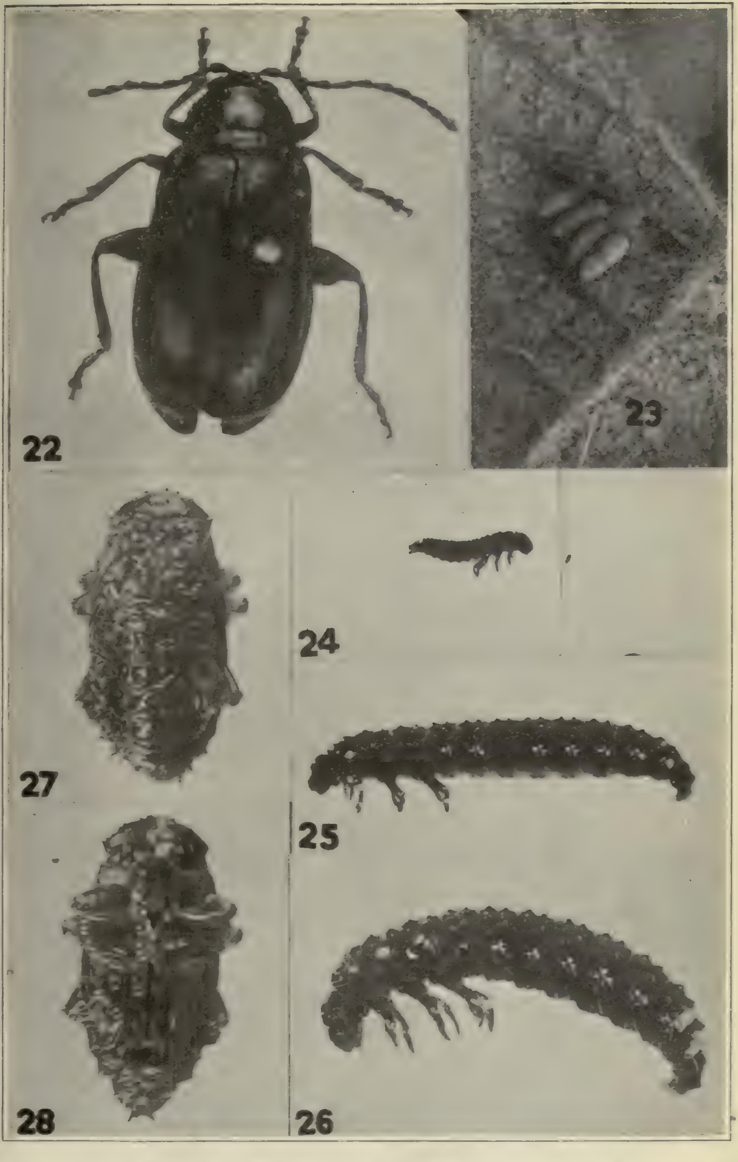


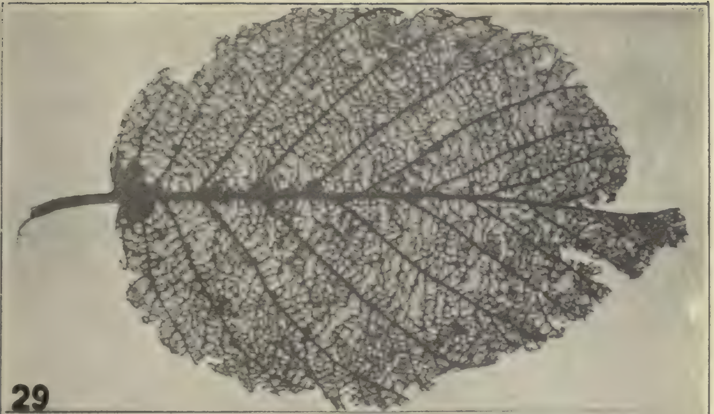
Altica bimarginata, larva. Fig. 18A: dorsal aspect, showing setae; fig. 18B: ventral aspect, showing setae; fig. 18C: lateral aspect, showing setae; fig. 19A: labrum; fig. 19B: mandible; fig. 19C: maxillae and labrum. For explanation see pages 258-260. Setae marked with an asterisk (*) are never found in first and second instar larvae and may be wanting in the third instar.



Altica bimarginata. Fig 20A: larval leg, ectal aspect; fig. 20B: ental aspect; fig. 21A: dorsal aspect of pupa, showing setae; fig. 21B: ventral aspect of pupa showing setae; fig. 21C: prothorax of pupa showing setae; fig. 21D: pygidium of pupa showing setae. For explanation see pages 260 and 265-267.



Altica bimarginata. Fig. 22: adult; fig. 23: eggs; fig. 24: 1st instar larva; fig. 25: 2nd instar larva; fig. 26: 3rd instar larva; fig. 27: pupa, dorsal aspect; fig. 28: pupa, ventral aspect.



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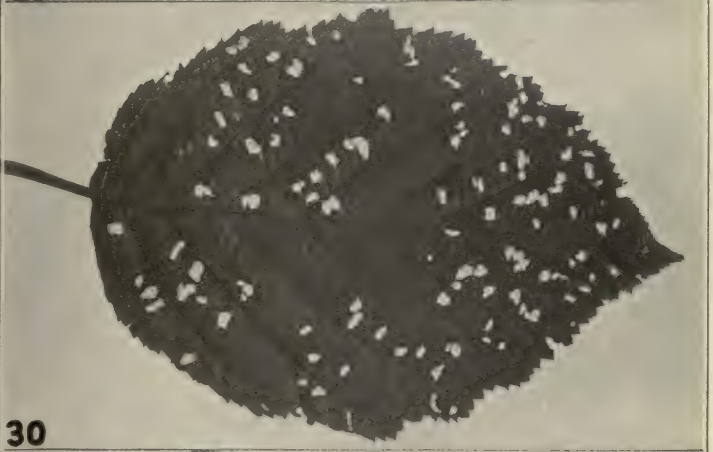

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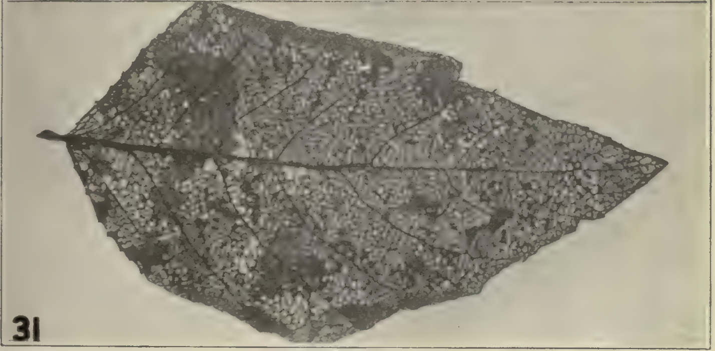

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Altica bimarginata. Fig. 29: work of larva on alder; fig. 30: work of adult on alder; fig. 31: work of larva on balsam poplar,

University of Maine

Maine Agricultural Experiment Station

ORONO

BULLETIN 267 NOVEMBER, 1917

THE APHID OF CHOKE CHERRY AND GRAIN.

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† In collaboration with U. S. Department of Agriculture.

BULLETIN 267

THE APHID OF CHOKE CHERRY AND GRAIN.[1]

Aphis pseudoavenae sp. n.

EDITH M. PATCH.

Late in June, 1917, a group of choke cherries on the campus of the University of Maine were found to be heavily infested with a species of aphid which I had not previously taken, although specimens of the same thing were brought me from Fort Kent, Maine, July 6, 1916 where they were found by Professor C. L. Metcalf while collecting syrphids.

Mounted specimens of this aphid would be most likely to be determined as *Aphis avenae* (i. e. of American authors) because of the constriction before the flange of the cornicle, the arrangement of the sensoria of the antennae, and the rather long, pointed stigma and the noticeably short second branch of M in the wing.

However, the fresh colonies crowded close along the stem and ventral leaf would suggest at once the *Aphis rumicis* group on acount of the conspicuous areas of wax powder, and could not be mistaken for *avenae* in life.

DESCRIPTION FROM LIFE.

SPRING CHOKE CHERRY GENERATIONS.

Apterous viviparous female: A rather old individual had body dark olive green irregularly mottled with still darker. Areas of powder especially noticeable in lateral rows of spots on abdomen, one on each side of segments just dorsad of prominent lateral crease, and over the tip of the abdomen caudad cornicles. These white areas are conspicuous on undisturbed colony but the powder is soon shaken off from collected material and then the aphids show only a general rather slight pulverulency. There is a deep purplish area (internal) at the base of each cornicle. Tibiae and base of antennae pale, cauda and cornicles black. Cornicles with constriction before flange with perhaps a suggestion of constriction at middle. Beak short, scarcely reaching second coxae.

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[1] Papers from the Maine Agricultural Experiment Station: Entomology No. 95.

Alate viviparous female: Head and thoracic lobes glistening black, general body color dark olive green. Breastplate, anal plate, cauda and cornicles black. Cornicles constricted before flange and tendency toward a very slight midconstriction. There are three large, heavy, black spots along lateral line of abdomen cephalad the cornicles, and an irregular black patch at base of cornicle, caudad. The second branch of M is typically near margin of the wing, though there is considerable variation in the length of this branch. The shape and length of stigma is variable but it is always pointed and rather elongate. The relative length of the antennal segments and the number of sensoria are also unstable factors. The drawings show what is a good average. Sensoria are always present on III (25 more or less), and IV (10 more or less) and usually on V (a few). The beak reaches about half way between first and second coxae.

Spring nymph developing to alate female: The newly dropped or newly molted nymph is yellowish or pale brown, with rusty area (internal) at base of cornicle. The nymph soon colors to dark olive green.

INSTAR	ANTENNA	BEAK
1st.	4-segmented	just caudad 3rd coxae
2nd.	5-segmented	reaches 3rd coxae
3rd.	6-segmented	2nd coxae or beyond
4th. (pupae)	6-segmented	not reaching 2nd coxae.

In the pupal instar this nymph is dark olive green, with five lateral powder spots on each side of abdomen cephalad cornicles and a solid powder area caudad the cornicles. Powder spots are present on base of head and on prothorax. There is a dark rusty area at base of cornicle due to internal substance showing through the body wall. Cauda is pale at base with black tip, and the cornicles are black.

GRAIN GENERATIONS.

Apterous viviparous female. Unlike their choke cherry progenitors, the summer colonies do not share pulverulency in any instar. In general body color they are soft dark green, dull amber greenish, to very pale greenish; always unmarked by any darker green streaks and always with strong rusty space at base of cornicles and often connecting them, a color being due to internal structure showing through the body wall.

Alate viviparous female. The laboratory bred specimens had olive green abdomens with black lateral spots, a black patch at caudal base of cornicle and some black median dashes caudad the cornicles.

SUMMER FOOD PLANTS.

Migration tests were made by placing the winged June forms on various grasses. The progency of the migrants accepted the following: Timothy, Kentucky bluegrass, sheep fesque, meadow fesque, red top, barley and oats. The test was continued through one generation only, except with the oats which was used during the summer for the material under observation.

LIFE CYCLE.

No data are yet available for the stem female as the first choke cherry collection was made June 25. At this time both apterous and alate viviparous females were present, the latter being recently developed as was evidenced by the abundance of individuals in the pupal instar.

The migrants were already taking wing on June 25th and the process continued for a week or so longer.

No collections were taken in the field in the summer here but in the laboratory material continued to live on oats until about the first of September, the colony dying out at that time partly from unknown causes.

DISCUSSION OF NAME.

Whatever the ultimate fate of the name proposed for this species may be, there seems to be no safely established American aphid to which to refer it. It is not the *avenae* of American authors which has well defined characteristic dark green longitudinal streaks entirely absent in *pseudoavenae*. It is not the *avenae* of Theobald (Canadian Entomologist, 1916 p. 235). It is not the *padi* described and figured by Koch and Buckton. Is it the *padi* of Van der Goot (1915 p. 241)? Possibly, "in part", though it is certainly not in accord with his collection from *Mespilus* and *Pirus malus*.

No such aphid has previously been recorded on its spring host in this country as it is none of the species listed from choke cherry.

That it has been taken on grain and confused with the apple grain aphid, the so called *"avenae"* of American authors seems not improbable as these two species are so much alike in structural characters that they would be distinguished with difficulty from mounted material. In life, however, they are readily separable especially in the spring generations with a simple hand lens, the characteristic dark green longitudinal lines of our so called *"avenae"* being entirely absent from all generations of *pseudoavenae* and the powder areas of the spring generations of *pseudoavenae* being particularly noticeable. Both species have a rusty internal area near the bases of the cornicles.

To designate this aphid as a new species seems the only way to preserve its life cycle from confusion at present.

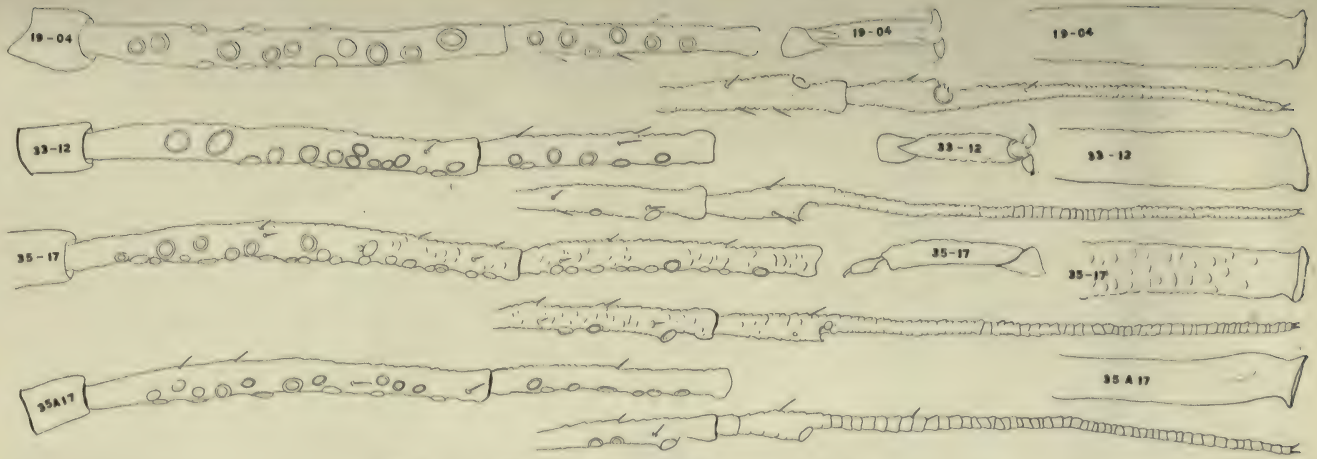

FIG. 32. THREE GRAIN APHIDS OF MAINE.

19–04. Antennal segments II to VI, tarsus, and cornicle of the spring migrant of an apple-grain aphid. Note relative length of cornicle and antennal segment VI.
33–12. Antennal segments II to VI, tarsus, and cornicle of the spring migrant of a hawthorn-grain aphid.
35–17. Antennal segments II to VI, tarsus, and cornicle of the spring migrant of a choke cherry-grain aphid. Note length of antennal segment IV, and the length of tarsus in relation to cornicle. 35A 17. Antenna and cornicle of an alate summer female of the foregoing on grain.

Too much emphasis should not be placed on the relative number of sensoria on segments III, IV and V as these are somewhat variable in all three species. The sensoria of the choke cherry-grain aphid, however, are consistently smaller than those of the other two species. All drawings are made to the same scale.

Issued February 12, 1918.

PORTO RICO AGRICULTURAL EXPERIMENT STATION,
D. W. MAY, Agronomist in Charge.
Mayaguez, P. R.

Bulletin No. 23.

THE CHANGA OR WEST INDIAN MOLE CRICKET.

BY

R. H. VAN ZWALUWENBURG,
Entomologist.

UNDER THE SUPERVISION OF
STATES RELATIONS SERVICE,
Office of Experiment Stations,
U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1918.

PORTO RICO AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

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LETTER OF TRANSMITTAL.

PORTO RICO AGRICULTURAL EXPERIMENT STATION,
Mayaguez, P. R., March 20, 1917.

SIR: I have the honor to tranmit herewith a manuscript by R. H. Van Zwaluwenburg, entomologist of the station, on the Changa or West Indian Mole Cricket. The changa or mole cricket, by far the most destructive insect known to the agriculturist in Porto Rico, causes enormous losses justifying the long series of investigations made of its life history and methods of control. This bulletin, which is the second publication by the station on the changa, carries the investigations much further than the first. It is not intended as final, however, as efforts will be continued to find more effective means of control, such as the discovery and introduction of natural checks.

I recommend that the manuscript be published as Bulletin No. 23 of this station.

Respectfully,

D. W. MAY,
Agronomist in Charge.

DR. A. C. TRUE,
Director States Relations Service,
United States Department of Agriculture, Washington, D. C.

Recommended for publication.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON,
Secretary of Agriculture.

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[1] On leave.

THE CHANGA OR WEST INDIAN MOLE CRICKET.

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IMPORTANCE.

The most serious insect pest of general agriculture in Porto Rico is the West Indian mole cricket (*Scapteriscus vicinus*) or "changa," as it is popularly called on this island. The latter name is derived from the fancied resemblance of the insect's head to that of a monkey (chango). Although other insects may be more destructive to special crops, as, for example, white grubs to sugar cane and flea beetles (*Epitrix* spp.) to tobacco, the changa causes such serious damage to agriculture in general that it takes first rank as an insect depredator. Barrett in 1902 (2, p. 5)[1] stated that "the changa's damages to tobacco, cane, and small crops in the island amount to probably more than $100,000 annually." Improved control measures have greatly reduced the loss to cane and especially to tobacco since that time. It is to the general gardener that the changa now does most harm. It should be recognized, however, that much damage done to miscellaneous crops by other crickets and by cutworms is mistakenly attributed to the changa, which, on account of its conspicuous size, is well known to even the most casual observer.

The mole cricket is found in neighboring tropical countries having about the same soil and climatic conditions as Porto Rico, but it is only in this island that the insect has become of serious importance in agriculture. Possibly some very effective parasite, as yet undiscovered, holds it in check in its other habitats, or, perhaps, a combination of circumstances, such as suitable soil conditions, favorable cultivation methods, and absence of certain predacious enemies, is the cause of the insect's greater destructiveness in Porto Rico.

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[1] Figures in parentheses refer to the bibliography found on pp. 25–28; other figures refer to footnotes.

CLASSIFICATION AND SYNONYMY.

The changa is a member of the insect order Orthoptera, which contains the roaches, walking sticks, mantids, grasshoppers, locusts, and crickets, and is said to number at least 10,000 known species.[1] According to recent systems of classification[2] the mole crickets, with their fossorial forefeet, form the family Gryllotalpidæ, but they were formerly considered as a subfamily of the cricket family Gryllidæ. The changa is the only mole cricket known to occur in Porto Rico.

The species was first described by Scudder in 1869 (41). Gundlach and Stahl both mention the insect as *Gryllotalpa hexadactyla*, which is a quite different species and is not known to occur in Porto Rico. Saussure in 1870 considered this species to be merely a variety of *S. didactylus*. Rehn and Hebard have recently published the opinion that "the species found abundantly in the southeastern United States, the West Indies, and portions of South America, and which has been frequently recorded as *S. didactylus*, represents instead *vicinus* of Scudder. This species is very closely related to *didactylus* of Latreille (described from Surinam and found elsewhere in South America and northward to Costa Rica), but is somewhat heavier." As given by Scudder in his table for the separation of species of Scapteriscus (41, p. 7), *S. vicinus* differs from *S. didactylus* in that the tibial dactyls almost or quite touch at the base, whereas in *S. didactylus* they are distant from each other at the base by at least one-half the width of the dactyls. Rehn and Hebard consider *S. agassizii* of Scudder synonymous with *S. vicinus*.[3]

HISTORY AND DISTRIBUTION.

In economic literature this injurious mole cricket has always been treated under the specific name *didactylus*, a name, as above stated, now applied to a closely related species. The first mention of the insect as a pest appeared in 1836 in letters from A. M'Barnet, of St. Vincent (32), who described the cricket as injurious to pastures and to cane plantings. Although the pest is named only as the "mole cricket," the insect in question is without doubt this species. Harris in 1862 (27) mentioned this species under the name *Gryllotalpa didactyla*, as destructive to sugar cane in the West Indies.

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[1] Sharp, D. Insects, I. Cambridge Natural History, vol. 5, p. 201. London, 1895.

[2] Brues, C. T., and Melander, A. L. Key to the Families of North American Insects, p. 14. Boston and Pullman, Wash., 1915.

[3] Since the above was written Mr. James A. G. Rehn, in a letter dated Apr. 7, 1917, has defined the range of *Scapteriscus vicinus* and *S. didactylus* as follows: "The limits of its [*S. vicinus*] range appear to be, as far south as Las Palmas, Chaco, Argentina, and Santa Cruz de la Sierra and Puerto Suarez, Bolivia; west to the Rio Pacaya, Peru; east to Piauhy, Brazil; and north to Colombia and Venezuela and through the West Indies, occurring also in eastern Georgia. The range of true *didactylus* appears to be limited to a relatively circumscribed area in northeastern South America from eastern Venezuela through the Guianas to lower Amazonian Brazil. This information on *didactylus* has not been published as yet, but is clearly evident from material in our collections."

Gundlach in 1886 (25) was the first writer to record the changa from Porto Rico. He states that it is not common in Cuba, but does considerable damage in Porto Rico, at least in the vicinity of Mayaguez. In 1887 the same writer (26) notes the flight of adults to lights and again mentions the insect as being especially abundant in Mayaguez. Brunner von Wattenwyl and Redtenbacher in 1892 (7) mention collecting this species in St. Vincent during January, and give the following localities as habitats of the insect: Haiti, Panama, Peru, Uruguay, and Argentina. In 1895 Fernando López Tuero, of the Spanish Agronomic Station at Rio Piedras, Porto Rico, gave a popular account of the changa as a pest of sugar cane (31) with notes on its life history.

The first extensive account of the changa was published in 1902 by Barrett (2), entomologist and botanist of the Porto Rico Agricultural Experiment Station. Like most of the previous writers, he used the specific name *didactylus*. He outlined the habits of the insect and gave recommendations for its control. According to him the changa has been very troublesome in Porto Rico only since the hurricane of 1876, which is supposed to have destroyed most of the insect's bird enemies. After 1885 the insect seemed to decrease slightly in numbers until the hurricane of August, 1899. It is the common belief in Porto Rico that the insect was introduced into the island about 1850 in a load of guano brought to Mayaguez. The first estate in Porto Rico to abandon cane culture because of the changa's ravages is said to have been the one in Mayaguez upon which the experiment station is now located. At present the insect seems to be more numerous and troublesome in the eastern part of the island.

The changa has become well established in the southeastern United States. In 1912 Worsham and Reed (54) published an account of the mole cricket's habits and development and the damage done by it in the coastal counties of Georgia, where it has been known since 1899 (11). Prof. J. R. Watson, of Gainesville, Fla., writes[1] that flourishing colonies of this insect have become established in the vicinity of Tampa and Miami, and he suspects that the insect is generally distributed throughout Florida, although there are only three authentic records of it from the State, all of them from the southern part. According to Dr. W. E. Hinds,[2] the species is probably present generally throughout Alabama, and complaints of its damage are not uncommon there. It is not known to occur in Louisiana.

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[1] Correspondence Sept. 29 and Nov. 16, 1916.

[2] Correspondence Oct. 25, 1916.

The changa has been found in St. Croix,[1] but is so rare there that no noticeable damage has resulted. It is not known to be present in Santo Domingo, although Haiti is listed in its range. "A species of mole cricket, said to be the same as the Porto Rican changa, appeared in such numbers in Venezuela several years ago that the cultivation of cane had to be abandoned." (20, p. 348.)

The present known distribution of the changa is as follows: Georgia, Alabama, Florida, Cuba, Haiti, Costa Rica, Panama, Porto Rico, Culebra Island (P. R.), St. Croix, St. Vincent, St. Lucia, Trinidad, Barbados,[2] French and Dutch Guiana, Brazil, Uruguay, Argentina, and Peru.

GENERAL HABITS.

The changa is essentially a subterranean insect, as all its developmental stages are spent in burrows. These burrows when just beneath the surface of the ground may be traced with ease as raised lines of broken earth winding about promiscuously. The insect seldom leaves its burrows, and then generally at night. During the day an adult is occasionally seen scurrying over the ground, but it soon enters the soil.

As may be expected from the mechanical difficulties to be overcome in burrowing through a heavy soil, the changa is never found in heavy clay lands, but in light, loamy soils. As a result the insect is much more abundant in the alluvial lands of the coast and in the inland river valleys than in the mountainous parts of the island, the soils of which are for the most part heavy clay. It is particularly abundant in light, compressible soils which allow tunnelling without the removal of loosened material. The insect avoids tunnelling on very sloping land, doing most of its work on level areas, although in very heavily infested territory even hilled-up plants are damaged. The galleries dug by the changa are more or less permanent in the heavier, loamy soils, and are used by all the changas in the immediate vicinity. The insect responds to moisture changes, as in the dry season its tunnels are carried to a depth of some 12 inches, while during the rainy season they are to be found usually within 4 inches of the surface, the depth at which the egg chamber is placed varying similarly with the season. A prolonged drought often causes an overland migration of adults and nymphs under cover of night to more favorable breeding and feeding grounds.

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[1] According to Mr. Holger Johansen, for some years a resident of that island.

[2] Correspondence from Mr. Wm. Nowell, Nov. 10, 1916.

The forefeet of the changa are powerful and remarkably adapted for digging, the joints of the foretibiæ and tarsi being so articulated as to form a sharp, curved, shearing apparatus. The hard, rounded prothoracic shield is well suited for shaping the sides of the tunnel by rotary movements as digging progresses and for firming the soil in the newly made galleries.

Although clumsy, owing to the weight of its specialized forelegs, the changa is a rapid runner, even on the surface of the ground, where it often accelerates its gait by short hops. In its underground galleries it is a very rapid traveler, moving forward or backward with equal ease. Changas of the first three stages are very active, hopping many times their own length and running with great agility. The saltatory power is lost in the later instars, as the forelegs become heavier, and in leaping, the insect often somersaults in midair. The adult is also a heavy, clumsy flier and after performing long swoops lands heavily. Migrating individuals have been recorded (54, p. 256) as soaring over tree tops, and such migration to the distance of a few miles is considered probable. Flight during daylight hours has not been observed in Porto Rico, but is recorded from Georgia (54, p. 262). The adults not uncommonly fly into lighted houses during the early evening, from dusk on, especially on damp, cloudy nights.

FEEDING HABITS AND FOOD PLANTS.

The changa feeds primarily on vegetables, animal food seeming to form only a small part of its diet. Almost any young plant growth is attacked. The insect remains underground and feeds from below, commonly selecting the crown of the plant as the point of attack. When the growth is very tender the insect consumes almost the entire sprout, pulling it into the soil while feeding until only the top leaves are left above ground. Sometimes the seedling is partially gnawed through at its base. Tender roots also are often eaten.

Of the staple crops, tobacco is the most seriously damaged. Owing to the use of the Paris green and flour mixture, the changa is not now so important a pest of this crop as it once was. Practically all the grasses serve as food for the mole cricket, "grama" (*Paspalum* sp.) and "yerba dulce" (*Elevsine indica*) being its favorites among the common wild species. When sugar cane is planted on loose or sandy soils the changa sometimes causes great damage to this crop. Its injury to the young canes often makes necessary a considerable amount of replanting before a stand can be obtained. The injury to cane is confined to the germinating seed and to the bases of the young shoots, which are partially gnawed through. The boring into cane, attributed by some writers to the changa, is probably the work of grubs. After the cane is about two months old and the young shoots have hardened, the changa is no longer a danger to the crop.

Most garden crops, and especially corn, tomato, cabbage, lettuce, and pepper, suffer severely from the changa. In the laboratory when sprouted corn was used for food the insect ate not only the stalk but in many cases the kernel as well. Nursery plantings of Livingstonea palm seedlings at the station were badly injured. Experimental plats of alfalfa were not damaged, although changas were present in the soil. Barrett (2, p. 9) has noted that plants having an acrid sap are usually free from attack.

The plants not acceptable as food are often injured by the changa's habit of trimming roots that lie along its path. Much damage of this kind may result from the active tunneling done by the insect.

The known food plants of the changa are tobacco, tomato, eggplant, potato, pepper, sugar cane, grama grass (*Paspalum* sp.), yerba dulce (*Eleusine indica*), Bermuda grass (*Cynodon dactylon*), rice, cabbage, collard, rape, turnip, cantaloup, sweet potato, lettuce, *Coleus* spp., and *Livingstonea* sp.

DESCRIPTION OF ADULT.

GENERAL DESCRIPTION.

The adult changa (Pl. I) is generally brownish in color with more or less constant darker markings. The average length without antennæ or anal cerci is about 30 millimeters (1¼ inches). Considerable variation in size is found, males varying from 19 to 34 millimeters and females from 24 to 36 millimeters.

HEAD AND APPENDAGES.

The large head is protected posteriorly by the pronotal shield. The black compound eyes are fairly conspicuous; just above and between them is a pair of pearly white, obovate, slightly convex ocelli. The antennæ arise at the lower margin of the eyes and between them; they are filamentous and about one-third the body length. The apparently unbroken antennæ of a male were composed of 87 segments, the largest number noted for the species. The clypeus is light brown and leathery and covers completely the black, heavily chitinized tips of the mandibles. The area just above the base of the clypeus is a mottled dirty white.

THORAX AND APPENDAGES.

The prothoracic shield is the most conspicuous part of the insect and is the only part of the thorax that can be seen from above. It is a tough, leathery, subovate, convex capsule, with darker markings on

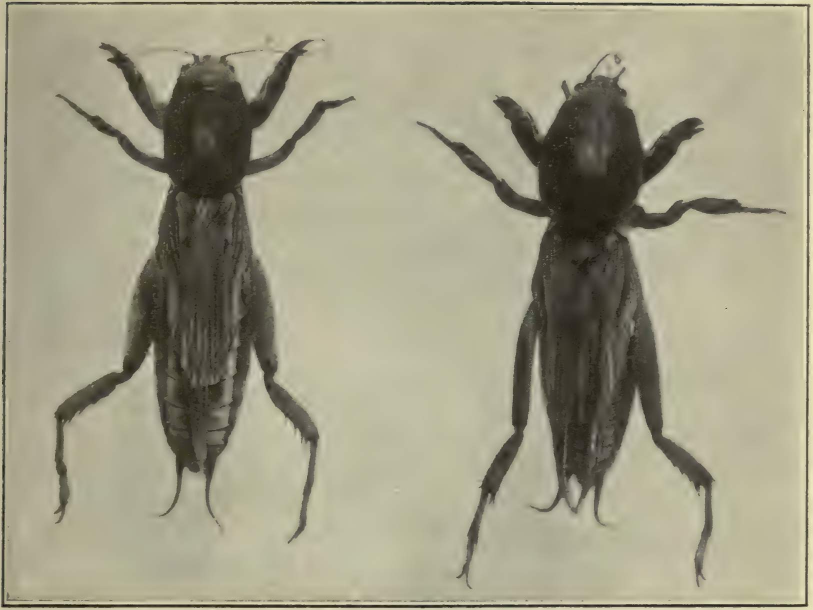


FIG. 1.—FEMALE CHANGA ON LEFT, MALE ON RIGHT.

Enlarged about two times.

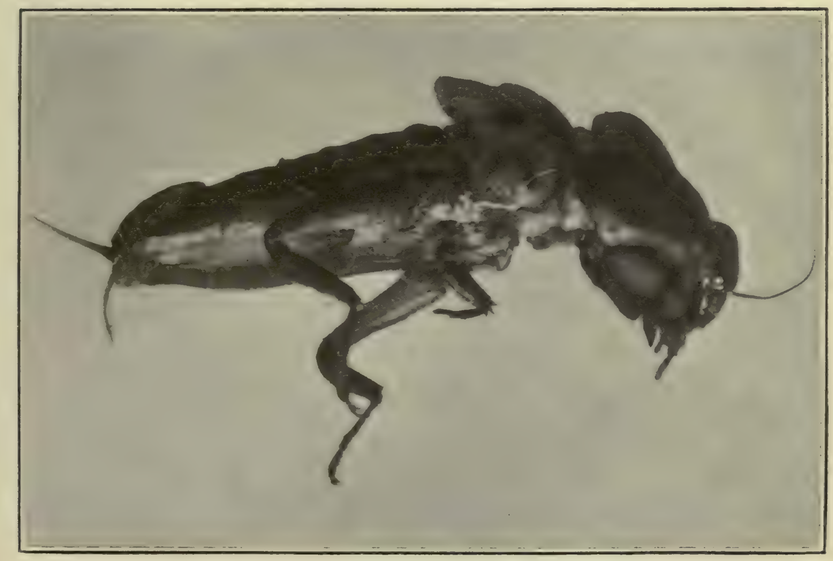
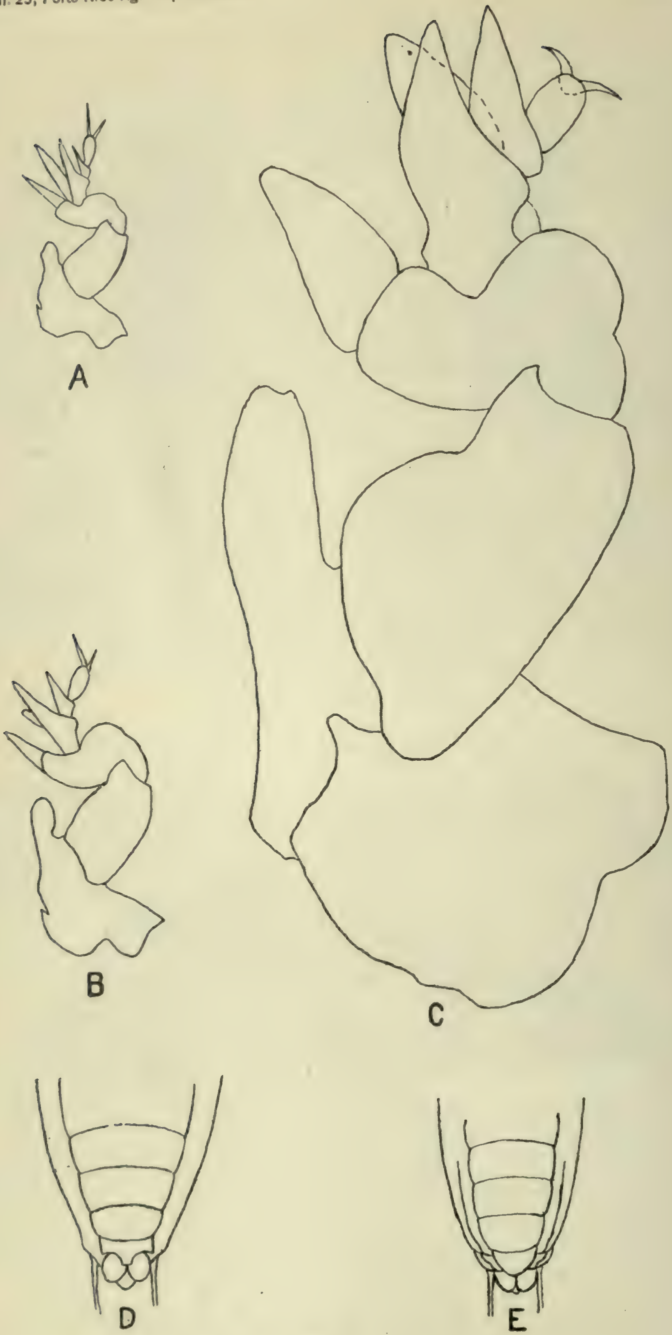


FIG. 2.—SEVENTH INSTAR MOLTING.

Enlarged about three times.

PLATE II.



ANATOMICAL STRUCTURE OF CHANGA.

A, Left foreleg, first instar; B, same, second instar; C, same, eighth instar; all enlarged about eleven times. D, Abdominal segments of male; E, same of female; both enlarged about three times.

the posterior half. Its sides extend a little below the front coxæ, and its anterior margin is concave.

The tegmina or fore wings are leathery and heavily veined and extend well beyond the middle of the abdomen. The venation of the tegmina differs with the sex, but there is no variation in the tegmina of an individual. In the male the vein which forms part of the musical apparatus, and which is located on the basal third of the tegmen, makes a distinct angle of about 100 degrees with the principal longitudinal veins. In the female the prominent veins are generally longitudinal, and there is no conspicuous cross vein. The second pair of wings is more ample and delicate than the tegmina, and more finely veined. The wings fold in plaits and their apical end is rolled, the tips extending beyond the tip of the abdomen but usually not reaching the ends of the anal cerci. The pleuræ and dorsum of the last thoracic segment are provided beneath the wings with long, fine, ruddy hairs.

The greatest specialization for subterranean life is seen in the fore legs. (See Pl. II, figs. A, B, C.) Their structure is strong and powerful. The coxæ and femora are thick and muscular and the finger-like dactyls are strongly chitinized. The trochanter is a chitinous blade which serves as a support and runner for the entire leg. The tarsal dactyls are just above and outside of the tibial dactyls, and the paired blades of these structures passing just out of plane from very sharp and powerful scissors.[1]

The tympanum of the auditory apparatus is located on the upper surface of the basal part of the tibia. Instead of being concealed in a protecting cleft or fold of the chitin, as is the case in a closely allied genus, Gryllotalpa, it is only partially protected by a chitinous fold and may be easily seen as an oval white membrane stretched over the auditory chamber.

The mesothoracic legs show no particular specialization. The hind legs have the femora well muscled for leaping, and the tibiæ are spined to assist, no doubt, in landing after leaping or flight. The terminal tarsal joint of the hind leg is high and vertically flattened.

ABDOMEN AND APPENDAGES.

The abdomen is provided on the dorsal and ventral surfaces with ruddy pubescence, and the first six abdominal terga have long ruddy hairs (similar to those found on the metathorax) diminishing in length on each succeeding segment. On the lateral abdominal plates there are eight spiracles, seven of which are easily seen, while the first is concealed under the tegmina. The anal cerci arise dorsally from the tenth abdominal segment and are about one-fourth the body

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[1] A fuller description of the fore leg is given by Scudder (41, p. 12).

length; they are unsegmented and provided with fine, long hairs. Their function is uncertain, but is probably sensory. The genito-anal orifice is terminal and is controlled by a three-lobed valve, one lobe of which is dorsal and the other two sublateral. In the male the posterior margin of the eighth abdominal sternum is produced into a central tooth which is docked at the tip. (See Pl. II, fig. D.) In the adult female there are only seven visible ventral segments in the abdomen (see Pl. II, fig. E), for the eighth, which is of lighter color than the rest and is not medianly prolonged into a tooth, is hidden by the seventh plate. This sexual difference can be clearly distinguished as early as the sixth instar, when, in the male the sternal tooth appears as a small median knob on the posterior margin of the sternum.

DEFENSIVE AND STRIDULATING ORGANS.

When disturbed the changa almost invariably ejects a fetid fluid from the anal orifice. Sometimes this fluid is expelled as a drop, which remains in place, but usually it is ejected to a considerable distance. The fluid itself is colorless or nearly so, but is usually discolored by the presence of soil particles. It is viscid, gives an alkaline reaction, and has a penetrating and unpleasant odor. According to Baumgartner (5) it is probably a product of Du Four's organ. All instars secrete this liquid and its use, no doubt, provides a very effective defense against enemies approaching from the rear.

The stridulating apparatus of the changa is simple. The under surface of the prominent transverse vein of the male tegmen bears a series of transverse chitinized ridges which gives the vein a filelike appearance. The characteristic chirp of the sex is made by "ruffling" the tegmina, so that the inner margin of one tegmen is drawn back and forth rapidly against the filelike vein of the other. The note produced is a short shrill chirp seldom lasting more than two or three seconds. Baumgartner (5) notes the presence of "feebly developed" stridulating organs on the female tegmina and concludes from his observations that the female also chirps. The writer has never heard the female make any note whatever.

LIFE HISTORY.

REMARKS ON BREEDING WORK.

The breeding work with the changa, summarized in this paper, was done in the insectary at Mayaguez, and all statements as to seasonal activity, duration of instars, and the like, are made for that locality only. It is likely that there is not much variation in the insect's life history at different points on the coastal plain, with the possible exception of the drier southern coast. The rainfall probably has more direct influence than air temperature does in bringing about variations in the life history of a subterranean insect like the changa.

The cage used in procuring data on egg laying was a rectangular wooden sash, 24 inches long, 8 inches wide, and 1 inch high. Lateral grooves inside the sash, in which panes of glass could be run, permitted the depth of soil placed between the panes to be regulated. With a half inch of earth, the depth found to be most satisfactory, the runways of the adults were always in sight and could be observed without removing the glass. The cages were placed horizontally and covered with a dark cloth to simulate natural conditions. Sliced potato was at first used as food, but later sprouted corn was substituted.

As eggs were laid they were protected from the parent changas by a zinc ring the height of the space between the panes. It is possible that the egg stage was affected by keeping the eggs in a location so much more liable to temperature changes than the natural egg chamber located some inches below the surface of the ground. However, incubation of eggs in the cages seemed to be influenced as much by the moisture content of the surrounding soil as by the air temperature. It was impossible to collect exact data on the relation of length of incubation to soil-moisture content.

The young changas upon hatching were isolated in shell vials 5 inches long and 1 inch in diameter, which contained sand and sprouted corn. The changas were measured and transferred to vials of fresh food once a week until arriving at the fourth instar. After the fourth instar they were transferred to 250-cubic-centimeter Erlenmeyer flasks containing earth and sprouted corn. All changas from the fourth instar on were measured and transferred to fresh flasks every second day. Moisture conditions in vials and flasks were kept as near the optimum as possible.

Individuals reared from the egg were noticeably smaller when the final instar was reached than those taken in the field in the fourth instar or later and brought to the adult stage. The former individuals averaged about 3 millimeters less in body length and about 1.5 millimeters shorter in medial length of the pronotum.

It is not probable that the unnatural conditions under which the rearing work was done affected the length of the developmental stages very seriously, for nearly mature changas taken in the field and brought through to the adult stage in the laboratory averaged about the same length of time for the last two instars as did individuals reared from the egg. Furthermore, the total length of the egg stage and developmental and preoviposition periods, as determined in the laboratory, equals about one year, which corresponds with field observations. In nature the postembryonic developmental stages are perhaps somewhat shorter than in the insectary.

SUMMARY OF LIFE HISTORY.

As a rule, there are eight molts after the egg stage, although occasional males molt only seven times. The entire period from the egg stage to the adult averaged 295.3 days for 19 individuals, 11 of which were males averaging 281 days with a variation of 233 to 321 days, and 7 females averaging 321 days, with a variation of 291 to 397 days. About a year is required for the full development of a generation.

The duration of the different instars is shown in the accompanying table:

Duration of instars of changas reared from the egg.

Instar.	Number of individuals averaged.	Duration in days.		
		Maximum.	Minimum.	Average.
1	52	67.5	23.0	40.2
2	38	59.5	13.0	29.4
3	31	65.0	12.5	26.8
4	32	58.5	16.5	27.5
5	27	49.0	18.0	30.0
6	20	94.5	25.0	47.5
7	17	62.0	27.0	45.7
8	15	75.5	38.0	54.1

The preoviposition period of adult females is long. Three individuals averaged 79 days between the time of becoming adult and the first egg laying, 62 days being the shortest time and 93 the longest for this period.

That adults may live several months under favorable circumstances was shown by tests made with adults placed in battery jars filled with earth and provided with ample vegetable food. The longest adult life recorded was of a male which was eaten by a female 160 days after the final molt. An adult female taken in the field died a natural death after being kept alive for 127 days.

The numerical proportion of males to females bred in captivity was about equal, and the same is true of captures made in the field. Individuals have been brought to the adult stage every month of the year in the insectary, but there seems to be a fairly well-defined preponderance of final molts during the fall months. It is possible, therefore, that the flight to lights so marked during October, November, and December is in part at least a nuptial flight. All stages may be found in the field at any time of the year.

EGG STAGE.

The newly egg is gray in color and oblong-oval in shape, with a shiny, unsculptured surface (Pl. III, fig. 1), measuring about 3 millimeters long and 1.7 millimeters wide. The egg increases con-

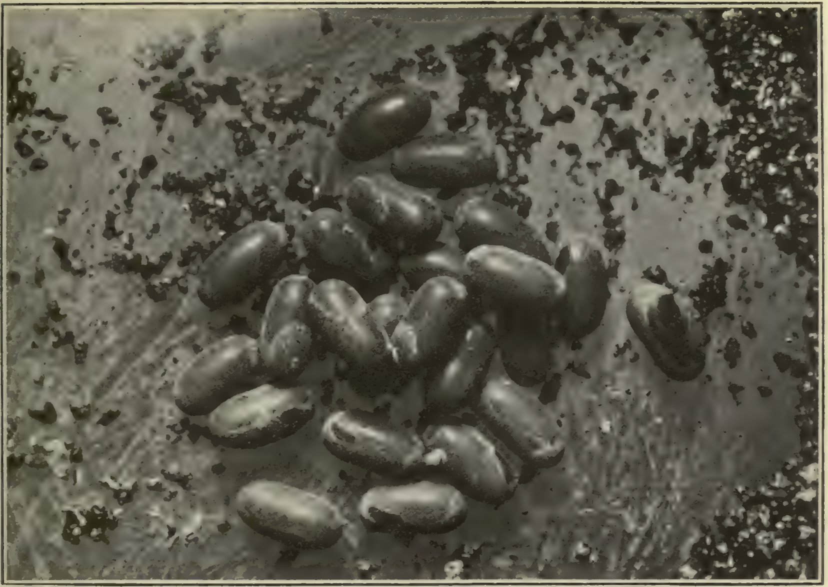

FIG. 1.—NEWLY LAID CHANGA EGGS IN EGG CHAMBER.

Enlarged five times.

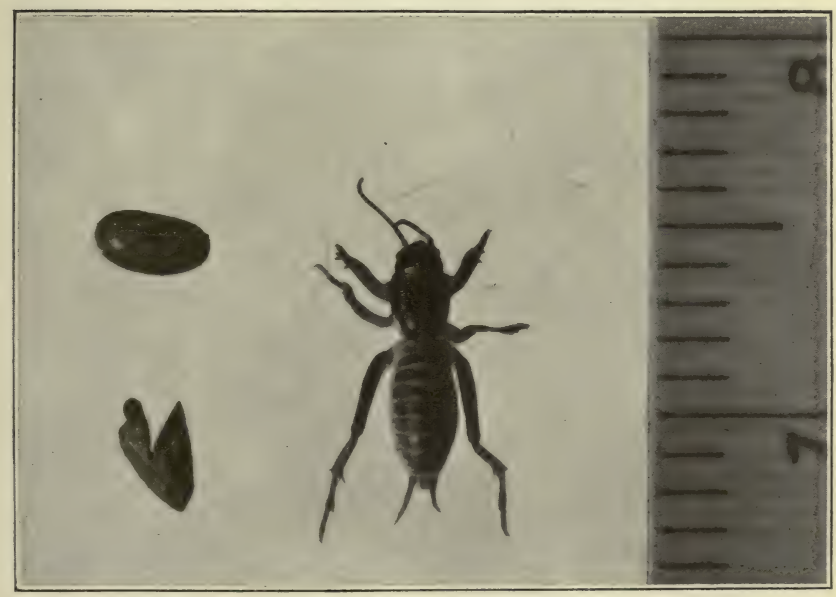

FIG. 2.—TEN-DAY-OLD EGG, EGGSHELL, AND FIRST STAGE OF CHANGA.

Enlarged five times.

siderably in size as the embryo develops, and five eggs within two or three days of hatching averaged 3.9 millimeters in length and 2.8 millimeters in width.

The eggs are deposited in an oval chamber measuring about 1½ inches long, 1 inch high, and 1 inch wide. The depth at which this chamber is located varies with the time of year at which it is made, as in the dry season it is some 8 inches underground, while in the wet season it may be within 3 inches of the surface. The chamber is a blind pocket leading off from one of the galleries; its entrance is concealed by a packing of loose earth after the eggs are laid to protect them from nymphs or adults. The eggs are dropped by the female in a loose heap. Egg clusters laid in captivity had an average of about 20 eggs, the largest heap containing 40, but in clusters found in the field the average rose to about 25. The egg is ejected very quickly, and the insect usually rests for a second or two before ovipositing again.

The greatest number of eggs deposited by any one female in captivity was 110 in four lots, and an examination of females taken in the field (some of which had no doubt already begun laying) failed to show more than this number of eggs in the ovaries. The changa laying 110 eggs, adult when captured, began to oviposit after 21 days, continuing for 57 days at intervals which averaged 18 days and dying the day the last cluster was laid. This was the longest oviposition period observed. Females in captivity deposited eggs every month of the year except December, the greatest activity being shown during April, May, and June.

The duration of the egg stage averaged about 19 days for 20 lots, with variations from 15 to 38 days. No relation was observed between the period of year at which eggs were deposited and the duration of the egg stage.

Besides increasing in size as development progresses the egg becomes ovate in shape, owing to the greater enlargement of one end, and changes from its gray color when first laid to a dirty, yellowish white. For some time before hatching occurs the chitinized mouth parts of the young changa within can be seen as a dark spot near one end of the egg. At hatching the chorion of the egg splits longitudinally, and the young changa emerges, backing its abdomen out first and lastly withdrawing its head from the shell. Under natural conditions practically all of the eggs hatch, only an occasional egg of a cluster appearing to be infertile, and the few that do fail to hatch are usually eaten by the first arrivals of the same brood. Eggs can not survive being deposited in a very dry location. Some eggs kept in the laboratory on dry sand for three weeks became shrunken and dry, and although they regained their original plumpness when placed on moist sand they failed to hatch. The check group from the same cluster hatched normally.

POSTEMBRYONIC STAGES.

With the exception of the dark-brown maxillæ and mandibles the newly hatched changa is snow white at emergence. A light oval area covers the greater part of each compound eye. Within an hour after hatching takes place the margins of the head, prothorax, legs, and antennal segments become dirty white, later changing gradually to a light gray. The abdomen is greenish white, acquiring a gray color more slowly and finally remaining lighter than the other parts of the body.

After leaving the egg the young changa is very active and begins feeding almost at once, not requiring care from an adult as a European mole cricket (*Gryllotalpa* sp.) is said to do.[1] Its diet consists of plant food, the weaker members from the same egg cluster, and perhaps an occasional egg. As the food requirements are small during this instar and the three stages following it, no noticeable damage is done to plants. One changa used in a starvation experiment survived the first instar without any food and died 22 days after hatching while in the act of the molting for the first time. At first the little changas are gregarious, but they soon wander off to the main gallery or make tunnels of their own.

In the first stage the changa is about 6 millimeters long, not including antennæ or cerci (Pl. III, fig. 2). The pronotal shield measures about 1.9 millimeters in median length and about 1.6 millimeters in width. The antennæ consist of 34 segments; no ocelli are present. The wing pads are not apparent on the first two abdominal segments. The tympanum is present on the foreleg. The foreleg itself is more slender than in later instars and has not the high specialization for fossorial life than it later acquires.

The succeeding stages of the changa resemble the first stage more or less, practically the only differences being in size and in development of the forelegs and of the wings. The wing pads are first noticeable in the second instar as small lateral projections of the dorsal plates of the first two abdominal segments. These budlike wing pads increase in size with each succeeding molt and become plainly noticeable in the fifth instar. The number of antennal joints increases with each instar from the 34 found in the newly hatched changa to well over 80 in the eighth-stage individual. The ocelli first become noticeable in the second stage, when they can be seen as elongate, hyaline, raised areas. The sternal tooth on the abdomen of the male can be discerned in the sixth stage, appearing as a small knoblike projection on the middle of the posterior margin of the eighth plate.

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[1] Sharp, D. Insects, I. Cambridge Natural History, vol. 5, p. 336. London, 1895.

The average measurements of the different instars of changas bred from the egg and from individuals taken in the field are shown in the following tables:

Average measurements of changas.

BRED FROM EGG TO ADULT STAGE.

Instar.	Pronotum.		Wing pads.		Body length.
	Length.	Width.	1	2	
	Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1	1.9_{55}	1.6_{3}			6.1_{10}
2	2.9_{46}	2.4_{4}			8.9_{2}
3	4.1_{38}	3.4_{21}			13.1_{3}
4	4.9_{33}	3.9_{22}			16.3_{6}
5	5.8_{31}	4.8_{20}			18.9_{7}
6	6.5_{27}	5.3_{20}		2.1_{4}	21.4_{5}
7	7.1_{15}	5.9_{15}	2.5_{9}	3.1_{15}	23.0_{9}
8	7.6_{14}	6.5_{14}	4.9_{12}	6.3_{13}	26.6_{11}
Adult	7.8_{14}	6.9_{15}	12.2_{6}	18.3_{6}	27.5_{8}
Female	7.6_{5}	6.8_{6}	12.3_{3}	19.2_{3}	27.5_{4}
Male	7.9_{9}	6.9_{9}	12.1_{3}	17.5_{3}	27.5_{4}

CAPTURED IN FOURTH INSTAR OR LATER AND BRED TO ADULT STAGE.

Instar.	Pronotum. Length.	Pronotum. Width.	Wing pads. 1	Wing pads. 2	Body length.
7	7.6_{10}	5.9_{9}	2.7_{2}	3.2_{6}	25.2_{2}
8	8.3_{26}	6.6_{26}	5.2_{20}	6.7_{20}	26.6_{18}
Adult	9.1_{70}	7.3_{70}	15.5_{23}	20.7_{29}	30.4_{25}
Female	8.9_{38}	7.3_{38}	15.6_{16}	21.4_{18}	31.1_{16}
Male	9.3_{31}	7.4_{31}	15.1_{7}	19.5_{11}	30.4_{9}

NOTE.—Inferior figures indicate the number of individuals averaged.

MOLTING.

Molting, as a rule, takes place underground in a cell constructed for the occasion and similar in shape to the egg chamber, though the process can be successfully accomplished above ground also. The skin splits dorsally from the front margin of the thoracic shield to about the third abnormal segment (Pl. I, fig. 2). First the thorax and abdomen are freed, and finally the head, legs, and antennæ. The entire process takes less than half an hour, and within two or three hours the body has regained its normal colorations. For a week or more before molting the changa is noticeably yellowish in color, and the wearing off of the pubescence covering the body gives it a greasy appearance. After molting the changa is dark brown to black, with a fresh, velvety appearance produced by the new pubescent coat.

Two males reached the adult stage with the normal tegmina of this species, but with metathoracic wings aborted and completely hidden by the fore wings. Not uncommonly changas in capacity are found unable to free the legs and mouth parts in molting.

NATURAL CONTROL.

The natural control of the changa, that is, its reduction to unimportant numbers by natural enemies, either parasitic or predacious, is obviously a failure in Porto Rico. The insect has numerous enemies, but their combined efforts are not sufficient to hold the mole cricket in check.

PARASITES.

In Cuba an unidentified Tiphia (10) has been reported as a probable parasite of the changa, but it has been found only once. It was recovered from a changa burrow with portions of a mole cricket's exoskeleton worked into the cocoon. In Georgia, a tachinid fly is said to parasitize impoverished females, but this is more a scavenger than a parasite (54, p. 261).[1]

No parasitic enemies of the changa have been reported from Porto Rico. Two eighth-stage females kept in confinement during the breeding work were found after death to contain vast numbers of nematodes. These individuals had a peculiar "slick," greasy appearance for some weeks before they died. Prof. Henry B. Ward,[2] of Urbana, Ill., to whom one of the changas was referred, stated that there was little doubt that the nematode in question is a true parasite, but that identification of the material was impossible.

PREDACIOUS ENEMIES.

Insects, myriapods, reptiles, etc.—Several vertebrates and invertebrates feed upon changas in all stages; some, because of their nocturnal or subterranean habits, probably are important enemies of the mole cricket.

The common centipede (*Scolopendra alternans*)[3] probably occasionally feeds on the mole cricket. Its nocturnal habits, its liking for locations beneath boards and stones where changa burrows most frequently come to the surface of the ground, and its very rapid movements in attack, together with its generally carnivorous habits, make it very likely that this myriapod feeds on changas under natural conditions. In the insectary, on more than one occasion, a centipede entered the flat rectangular cages in which mated pairs of changas were confined and devoured the insects. Centipedes in captivity killed changas as fast as they were offered, far in excess of their food needs. The myriapod strikes and coils itself about its victim with great rapidity, generally attacking on the side behind and beneath the thoracic shield. Paralysis of the limbs follows almost at once, and in from 3 to 10 minutes the changa is lifeless.

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[1] Also correspondence from Mr. W. V. Reed, Nov. 17, 1916.

[2] Letter of Mar. 1, 1917.

[3] Determination made through the kindness of Mr. Roy W. Miner, American Museum of Natural History, New York.

A large gray hairy spider, called 'araña peluda," is not uncommonly found in the soil and may account for an occasional changa. Individuals in captivity devoured the mole crickets greedily.

Tower (46) records the adult of *Tetracha sobrina infuscata* as an enemy of the changa in the tobacco district in the interior of the island. This tiger beetle seems to be generally distributed over the island but is not very common.

Calosoma alternans is another probable enemy of the mole cricket. An adult female of this species was found in a changa burrow at a depth of about 6 inches. In the laboratory the beetle killed four changas in about two weeks and fed upon them from time to time. This insect, which is also predacious on small Lepidopterous larvæ, may be a more effective enemy of the mole cricket under natural conditions, but it is not a very common species.

Larvæ of *Pyrophorus luminosus*, in the absence of other food at least, will attack changas of any stage. This generally beneficial insect which is so common in the lowlands may be an effective enemy of the mole cricket.

In Cuba a red ant known locally as "hormiga brava" attacks the changa in its burrows and may be an important factor in keeping down its numbers. This is not the same species as the Porto Rican ant which has the same common name.[1]

The value of the various lizards (*Anolis* spp.), so numerous over the island, as predators of the mole cricket is very small because of their diurnal habits. A changa emerging above ground during the daytime, however, is almost certain to furnish a meal for some lizard.

The larger "siguana" (*Ameiva exul*) has the reputation of being a valuable enemy of the changa, and since it is a burrowing animal no doubt it does feed to a greater extent on the mole cricket than do the more common and smaller lizards. The stomach of an Ameiva collected at Yabucoa and examined by Mr. Wetmore contained fragments of a changa, and this species has been observed to dig out and devour mole crickets at Rio Piedras.[2] However, examination of the stomachs of four of these lizards taken at Mayaguez failed to reveal any traces of changas. In St. Lucia it is reported (6) that "previous to the introduction of the mongoose the mole cricket was kept under control by its natural enemy the ground lizard." This possibly refers to *Ameiva* sp.

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[1] Correspondence from Mr. Patricio Cardín, entomologist of the Agricultural Experiment Station at Santiago de las Vegas, Cuba.

[2] Letter from Mr. E. G. Smyth, of the Porto Rico Insular Experiment Station, Feb. 7, 1917.

Fredholm (18) states that the common Trinidad garden toad gorges itself upon the mole cricket. This is a South American species and maintains itself only where the mongoose is kept down. There are at least two species of Texas toads, nocturnal in habit and generally insectivorous, which might upon introduction reduce the numbers of the Porto Rican mole cricket (48) were it not for the mongoose which now overruns the island.

Birds.—The most efficient enemies of the changa are to be found among the native birds. The comparative value of the various species has been determined by Wetmore (53), from whose publication the following notes are taken:

> The blackbird (*Holoquiscalus brachypterus*), popularly considered one of the greatest enemies of "la changa," in reality destroys but few. * * * Other species, however, make up for the blackbird's shortcomings, and among them the despised martinete (*Butorides virescens cubanus*), ridiculed for its ungainliness, ranks foremost. Standing watchfully, with head drawn in, among the short growth of the young cane fields, or walking with lengthened stride along the border of lowland pools, it spies and avidly swallows both adults and young of the mole cricket. The species at present known to aid in suppressing this pest number 21, and following is a list of them arranged somewhat in order of importance (figures following the name indicate the percentage formed by the mole cricket in the total bulk of the food):

Bird enemies of mole cricket.

[From Wetmore.]

	Per cent.
Martinete (*Butorides virescens cubanus*)	54. 33
Falcón (*Falco sparverius loquacula*)	28. 69
Playero (*Oxyechus vociferus rubidus*)	14. 42
Putilla (*Actitis macularia*)	10. 78
Garza (*Florida cærulea cærulescens*)	7. 23
Judío (*Crotophaga ani*)	5. 69
Ruiseñor (*Mimus polyglottos orpheus*)	3. 62
Clérigo (*Tolmarchus taylori*)	3. 04
Pitirre (*Tyrannus dominicensis dominicensis*)	2. 36
Juí (*Myiarchus antillarum*)	1. 27
Garzón blanco (*Herodias egretta*)	1. 00
Julian chiví (*Vireo latimeri*)	. 90
Zorzal (*Mimocichla ardosiacea portoricensis*)	0. 86
Múcaro (*Gymnasio nudipes nudipes*)	. 60
Canario de manglar (*Dendroica petechia bartholemica*)	. 25
Gorrión (*Coturniculus savannarum intricatus*)	. 25
Mozambique (*Holoquiscalus brachypterus*)	. 21
Calandra (*Icterus portoricensis*)	. 21
Pajaro bobo (*Coccyzus minor nesiotes*)	. 21
Zorzal negro (*Margarops fuscatus fuscatus*)	. 16
Becacina (*Gallinago delicata*), one bird only examined	

> The Cuban green heron [martinete] is one of the commonest birds in Porto Rico and is distributed all through the coastal plain. * * * Clumps of bamboos along streams were favorite perches. To these growths numbers retired to escape the burning heat of the midday sun, and in many localities they were used as nesting sites. Most of these birds, however, still nest in the mangroves and swampy growths bordering lagoons and lowland streams. * * * Three stomachs [of this species] taken in January and two in August contain little else [besides bodies of the changa], while the smallest proportion—13 per cent—occurs in the month of June.

> [This bird] from the standpoint of the agriculturist is one of the most important species on the island. It should be protected, especially at nesting time, and encouraged by planting bamboos as permanent shelters along streams and drainage ditches. This species should hold its own and even increase largely, because of its adaptability to new conditions. The south coast especially, with the present area under irrigation, * * * is very favorable to the green heron, and this bird is one of the few economic species especially adapted to that region.

The Porto Rican sparrow hawk or falcón (*Falco sparverius loquacula*) is another important enemy of the changa, the insect constituting about 29 per cent of this bird's total food. It is most common in the foothills.

> To encourage the birds about cane fields occasional high perches from which they can watch for prey should be provided along the fences. Their numbers should increase in the lowland region, as their natural food [consisting mainly of lizards and mice, in addition to insects] is abundant and easily obtained.

Wetmore adds that although valuable insect-feeding lizards are eaten by the falcón, the reptiles are so numerous that no impression is made upon them, and this bird must be considered as a valuable species because it feeds so largely upon the changa.

In St. Vincent the West Indian hawk (*Buteo antillarum*) is recorded by Clark (12) as feeding to some extent upon the mole cricket, since the lizards, its more usual food, have been so greatly reduced in numbers by the mongoose.

Domestic animals.—Barnyard fowls, especially chickens, have long been recognized as voracious feeders on the changa. Comparatively few of the mole crickets are accessible to them, and their usefulness is thereby restricted to areas which are being plowed or spaded. One writer (43) records that chickens in St. Vincent are frequently killed by devouring live mole crickets which burrow out of the alimentary canal. At this station two native Porto Rican chickens about 2 months old were fed upon corn and live changas of all stages for about a week with no ill effects.

Hogs, which are valuable in cleaning land of white grubs, are not averse to devouring changas. In very badly infested areas good results may be secured by turning in hogs to feed before setting out the crop.

FUNGUS AND BACTERIAL DISEASES.

A small percentage of changas in the breeding cages died from what seemed to be a fungus disease. An eighth-stage female which was submitted to Dr. Alden T. Speare, mycoentomologist of the Bureau of Entomology, of the United States Department of Agriculture, was found to be infected by *Metarrhizium anisopliæ.* Even under laboratory breeding conditions, which were by no means ideal as regards freedom from fungi, only about 1 per cent of the changas handled could be even doubtfully classed as killed by this fungus.

Two experiments on a small scale with *Micrococcus nigrofaciens*, a bacterium pathogenic to white grubs and to some Blattids,[1] resulted negatively as far as the changa was concerned.

CANNIBALISM.

Cannibalism among changas is common under laboratory conditions. When changas were kept in pairs, although provided with plenty of vegetable food, one or the other sex was almost certain to be killed within a month. Under natural conditions cannibalism is probably greatest during the first few days following the hatching of an egg cluster. At that time the newly hatched changas remain together in their chamber, and a few of the weaklings, as well as some of the eggs, serve as food for the stronger or earlier hatched members of the brood. Both adult males and females devour the eggs when opportunity offers, but in nature they rarely happen upon the egg chamber. Imperfectly molted individuals in the breeding jars were often killed by other changas.

ARTIFICIAL CONTROL.

Control measures for the changa may be divided into preventive and remedial. The value of either class depends entirely upon local conditions.

PREVENTIVE MEASURES.

Mechanical devices.—One of the earliest methods used in combating the changa was the wrapping of mamey leaves (*Mammea americana*) about the roots of seedlings in transplanting. This method was in use chiefly among tobacco growers and gardeners. Other leaves said to be effective in protecting the roots from the mole cricket's ravages are those of pomarrosa (*Eugenia jambos*) and ausubo (two species are included under this common name, *Mimusops nitida* and *Sideroxylon fœtidissimum*). This method of leaf-wrapping hinders the rooting of the plants and sometimes causes water to stand about the roots. Mamey leaves rose in price as they became more scarce, and their use practically ceased. Their place was taken by cylinders made of tin, heavy paper, or wire. Plants are set within these cylinders, and the top of the cylinder allowed to project on inch or two above the surface of the ground. These cylinders are expensive, and in addition, those of tin and paper cause unnatural rooting conditions. Mamey leaves and cylinders will always be used to some extent in small gardens for valuable plants, but their use on a large scale is past.

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[1] Northrup, Zae. Michigan Sta. Tech. Bul. 18 (1914).

Repellents.—The most satisfactory repellents are flowers of sulphur and naphthalin flakes, though neither of these is completely successful where changa infestation is very severe. Dry sulphur drilled in with corn at the time of planting offers fair protection. Powdered naphthalin laid in parallel trenches ½ inch deep and 1 inch from the seed row is an effective repellent as long as it retains its odor, usually about three to five days. Naphthalin so used did not hinder germination of corn or lettuce. The high cost and extreme volatility of carbon bisulphid make the use of this chemical out of the question.

Kerosene emulsion is an effective repellent, but only at such strengths and in such quantities as to injure vegetation. Other materials found to be either useless as repellents or injurious to plant life are lemon oil, mustard oil, citronella, and creosote. Barrett (2) lists as unsuccessful repellents for the changa creolin, coal tar, lime, and tobacco (both as a dust and a stem mulch). Other writers have recommended heavy applications of "greasy manures" (22) and of kainit.

Methods of planting.—Planting of sugar cane in a perpendicular or slanting position has solved the changa problem for this staple crop. When one or two eyes are left above ground, shoots are produced out of reach of the changa. After the shoots have become sufficiently tough to resist further attack from the mole cricket, the sprouts may be partially covered over with earth. Leaving portions of the leaf-sheath over the eyes will also protect the tender sprouts from the changa.

Hilling-up is often successfully employed to protect plants against the changa, advantage being taken of the insect's aversion to making its burrows up slopes. However, the writer has seen heavily infested fields where hilling-up had apparently had no effect.

Clean cultivation of land in itself is not an effective means of protecting the crop which is to follow. It should be considered only as a step in preparing for the use of poisoned baits. Although the removal of all vegetation may cause the insect to migrate to other feeding grounds, migration takes place only after the absence of food for several days has made the pinch of hunger felt, and in a country where grasses grow so luxuriantly as in Porto Rico, keeping land clean for more than a week would be more costly than the result would warrant. In the laboratory the starvation period of both first stage and adult changas averaged about 22 days. In the field the presence of other insect food would lengthen this period.

REMEDIAL MEASURES.

Plowing.—Plowing is of great value in changa control, for large numbers of the insects are exposed to chickens, lizards, and other enemies. In addition, egg chambers are broken up and some eggs exposed to the sun, a few hours' exposure to the direct rays of the sun apparently preventing eggs from hatching.

Trapping.—During October, November, and December changas take flight in large numbers, most commonly on cloudy, overcast evenings. The insects appear in largest numbers just after dusk, few flying after 9 or 10 o'clock. The surprising fact was noted in captures at lights at Mayaguez and at Rio Piedras (on a single evening at the latter place) during October, 1916, that the females outnumbered the males more than two to one. This disproportion fell somewhat with later captures, but females were still in the majority in January, 64 per cent of the total catch belonging to this sex. A large proportion of the females captured during the fall were sexually immature.

A season's experience with trap lights has indicated that their use is not generally practical against the changa. It is only on the rare occasions when the mole crickets fly in large numbers that it will pay to operate a light trap, as at other times the catch will be very scattering. Observation will determine whether the insects are abroad in sufficient numbers to make the running of the light profitable.

The trap light should be very bright, and the pan of oil and water placed beneath should be as large as can be had. As the mole cricket is not attracted to the light, but only to its vicinity, it would pay in case only a small pan is available, to have the changas that fall outside the receptacle picked up. It is useless to keep the light going after 10 o'clock.

Large bonfires in the fall of the year are said to attract and destroy large numbers of the changa.

Traps made by sinking wide-mouthed bottles in the earth up to the mouth were found to be useless, even when baited with cornmeal.

Burlap bags are said to be successfully used as traps for mole crickets in the Isle of Pines. The bags are laid flat on the ground, inspected early each morning, and the crickets found under them are killed. Some writers state that mole crickets congregate beneath compost heaps and can be captured there in large numbers.

Flooding.—It may sometimes be found practical to flood areas easily reached by irrigation canals. Flooding formerly practiced [1] on a small area near the river at Central Fortuna is said to have resulted in a noticeable decrease in changa injury. Nymphs or adult changas are not killed even by complete submersion for three hours, and in the field all instars usually will make their way to the surface within that space of time. In laboratory tests, changas readily made their way to the surface through 6 inches of flooded soil, and once on the surface of the water they float easily, owing to their air-retaining, pubescent coat. Exposure for even a short time in the field will give insectivorous birds, such as the martinete, ample opportunity to devour them. Although active swimmers, probably few of the insects will escape the watchful eyes of the water birds.

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[1] According to Mr. Holger Johansen.

In four laboratory tests clusters of changa eggs, either newly laid or almost ready to hatch, failed to survive a submersion of 24 hours. The checks hatched normally.

Poison baits.—Poison baits against the changa are most successful upon small areas, such as garden plats. The cost is an important objection to their use over larger areas, although they have been found practicable by large tobacco planters. Success depends on having the land so clean of all vegetation that when the bait is applied the changas will be hungry enough to accept it greedily. As the native grasses are among the mole cricket's favorite food plants, clean culture applies to the grasses as well as to crop remnants.

The most satisfactory bait yet found is a dry mixture of 3 per cent Paris green with cheap flour. Flour of the poorest quality, even that ruined by weevils and moths, is satisfactory for this purpose, corn meal, cottonseed meal, and bran making good substitutes, though flour seems to be preferred by the changa. Barrett (2, p. 16) reported very satisfactory results from the use of a mixture of grass stems, molasses, and Paris green. The Paris green and phosphorus mixture used against crabs is said to be acceptable to changas as well.

The Paris green and flour bait may be applied in a shallow trench around the young plant at a distance of an inch or more from the main stem, it may be introduced into a changa gallery where it approaches the surface, or it may be spread broadcast over the land. The last method is applicable to especially heavily infested lands. After the area to be treated has been kept clean of vegetation for three or four days, the mixture should be applied, preferably in the late afternoon, at the rate of 300 pounds to the acre. The crop may be planted three to five days after spreading the bait. This treatment on cabbage beds at the Mayaguez station resulted in 50 per cent better stand on the treated plats than on the checks. The broadcast treatment has the added advantage of killing other injurious plant-feeding insects, such as other crickets and cutworms.

Mr. Harrison Johnson, of the Cayey-Caguas Tobacco Co., has the following to say[1] in regard to the use of the Paris green and flour mixture in tobacco plantings:

> I can give no definite figures, but in my opinion the success of a seed bed where this remedy is used is insured fully 50 per cent over another handled under old methods. This application enables the grower to plan for seed plants at a specified time, which is extremely vital to him, owing to the limited period available for planting. The application of flour-Paris green in the fields has likewise proven a blessing for a great many reasons; the percentage of loss is considerably less than when the mamey leaf was used, and the free seedling starts off unhampered at once; a more even stand is obtained, and the poison will undoubtedly reduce the changa population in the immediate fields very materially. The changa is no longer the menace to the tobacco planter who will avail himself of this proven remedy.

Experiments have failed to demonstrate any increased effectiveness for baits containing salt, citrus juice, molasses, or honey. A distinct objection to the use of sweetening substances is that they make the bait very attractive to ants, which soon carry the material away. Fowls and domestic animals, of course, should be kept from access to poisoned mixtures.

GENERAL REMARKS ON CONTROL MEASURES.

The changa is by no means impossible of control, even though the problem at times is discouraging to the general gardener. The use of poison baits, either alone or in conjunction with such measures as trapping or perhaps flooding, should make crop raising possible even in the most heavily infested areas. Vigorous remedial measures employed year after year in some of the tobacco districts have resulted in rendering unimportant what was once a most threatening enemy of tobacco seed beds. Similar results can be obtained with other crops, but it should be borne in mind that control measures must be consistently continued to prevent reinfestation. Probably it will always be necessary to employ artificial means against the changa in Porto Rico, and though the insect can never be stamped out completely, it may be controlled by the exercise of vigilance and energy.

SUMMARY.

(1) The changa is a native of the West Indies and South America, but does its greatest damage in Porto Rico. It is the principal insect enemy of general agriculture in the island.

(2) The insect feeds on almost any tender vegetable growth, usually attacking the plant at the crown just beneath the surface of the soil. It also does much damage by cutting roots that lie along its paths.

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[1] In correspondence.

(3) The life cycle covers about one year. About three weeks are required for the egg state; about nine months for development from hatching to the adult stage; and over two months for the preoviposition period.

(4) Although the mole cricket has many natural enemies, particularly among the native birds, it is not held in check by them.

(5) With the exception of a nematode, no parasitic enemies of the changa are known to occur in Porto Rico.

(6) During the fall months the changa flies in large numbers on damp, overcast evenings. The greater proportion of changas attracted to lighted areas are females. Flooding is of value wherever the location of fields makes water easily available.

(7) Naphthalin and sulphur are the only repellents found to be of any value, and even they are only partially effective.

(8) Sugar cane is protected from the changa by planting it in a perpendicular or a slanting position. Hilling up plants greatly reduces changa injury in gardens.

(9) The use of poison baits, together with clean cultivation of the area to be planted, is recommended. A mixture of cheap flour and Paris green is particularly acceptable to the changa.

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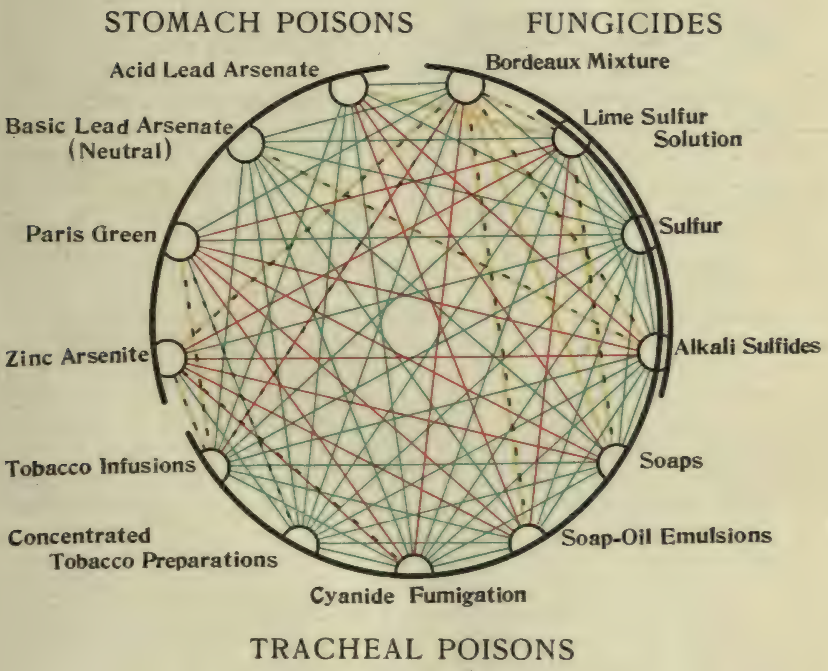
REVISED COMPATIBILITY CHART OF INSECTICIDES AND FUNGICIDES

BY GEO. P. GRAY



KEY TO CHART:

	Data lacking:
——— Dangerous combinations	— — — Probably dangerous
——— Recommended combinations	— — — Probably safe
——— Doubtful combinations, useful under some conditions	- - - Doubtful

PASTE ON A SHEET OF CARDBOARD AND HANG UP FOR CONVENIENT REFERENCE

REVISED COMPATIBILITY CHART OF INSECTICIDES AND FUNGICIDES

The present high cost of supplies and the scarcity of labor have brought the agriculturalist face to face with many new problems, not the least of which is that of pest control. With the exception of cyanide fumigation, the cost of an insecticide or fungicide is usually much less than the cost of its application. Spraying operations are often limited to a short space of time on account of unfavorable weather. The tendency to use, whenever possible, combination sprays in the control of two or more pests is thus accentuated. Untried combinations are apt to be made use of, sometimes with disastrous results to fruit and foliage. The matter of the compatibility, or incompatibility, of insecticides and fungicides, therefore, is now of unusual interest. In complex mixtures of this sort grave chemical or physical changes may take place which render the combination wholly unfit for use. On the other hand, the original ingredients may remain unchanged, or may be improved by their new associates.

Numerous experiments have been made to determine the advisability of various combination sprays and many of the results have been published in bulletins of the U. S. Department of Agriculture, the state experiment stations, and in agricultural journals. These reports are so scattered, and at times the conclusions of the various investigators are so conflicting, that one must spend much time in a search of the literature before arriving at a definite conclusion. In order to bring this information into more available form and to make it more easy of access, it was condensed into tabular form and presented before the State Fruit Growers' Convention in assembly at Davis, June 1–6, 1914. It is believed that this compatibility table and its discussion was the first comprehensive one of its kind ever made public. It was therefore presented with no little hesitation, and was considered as a tentative one only. Some little publicity was later given the table through its publication in at least six agricultural publications. Discussion and criticism were invited so that if any of the classifications were incorrect, or did not correspond with practical experience, the faults could be corrected. Since then, the matter has been followed closely, and minor corrections have been made to correspond more closely to the best practice. The original table has been simplified and arranged in the form of a circular chart,[1] and is now believed to be an accurate reflection of the best thought of the various investigators who have worked on the subject of compatibility of insecticides and fungicides. The accompanying revised chart is published in the hope that it will be of value in indicating the sprays which can be applied in combination, thus reducing the cost of application one-half, or in warning of dangers in apparently harmless mixtures.

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[1] The writer is indebted to Prof. C. A. Noren, Oregon Agricultural College, for suggesting the circular arrangement of the chart. A circular chart based upon the writer's original table and investigations by Mr. W. C. Morris, Hastings, New Zealand, has been published in the New Zealand Journal of Agriculture, vol. XII, no. 3, p. 193, and in the Fruit World of Australasia, vol. XVIII, no. 10, p. 17.

The stomach poisons are arranged about the upper left segment of the circle, the fungicides about the upper right segment, and the tracheal poisons (contact insecticides, gaseous, liquid, and solid) about the lower segment. Lime-sulfur solution, sulfur, and the alkali sulfides have important uses both as an insecticide and as a fungicide, consequently the segments upon which they are arranged are made to overlap, to indicate their double utility, and to avoid duplication and an unnecessary number of lines. The materials listed have been strictly confined to the standard remedies in common use in orchard spray practice. Colored connecting lines are made use of to indicate the effect of mixing. The color scheme of railroad signals has been adopted and is as follows: red, danger; green, proceed; yellow, proceed with caution. The meaning of the solid red and green lines appears to need no further explanation. A yellow connecting line is used to indicate that mixing is apt to produce chemical or physical changes which destroy the original properties or value of one or both of the ingredients, or that the mixture is recommended for use in certain sections, but not in others, or for certain specific purposes. The broken lines indicate combinations which have not been experimented with, or not sufficiently so to definitely establish their status. The probabilities are, however, indicated by the color scheme as nearly as can be judged.

For the use of the chart in connection with materials, the names of which are not listed thereon, the following list of equivalents has been arranged:

NAMES NOT LISTED	CORRESPONDING COMPATIBILITY
Coal-tar "Dips"	Soap-oil Emulsions
Dilead Arsenate	Acid Lead Arsenate
Dry Lime-sulfur	Lime-sulfur Solution
Iron Sulfide	Sulfur
Lead Hydrogen Arsenate	Acid Lead Arsenate
Liver of Sulfur	Alkali Sulfides
Miscible Oils	Soap-oil Emulsions
"Neutral" Lead Arsenate	Basic Lead Arsenate
Nicotine Sulfate	Conc. Tobacco Preps.
Potassium Polysulfide	Alkali Sulfides
Sodium Polysulfide	Alkali Sulfides
"Soluble" Oils	Soap-oil Emulsions
"Standard" Lead Arsenate	Acid Lead Arsenate
Sulfide of Potash	Alkali Sulfides
Sulfide of Soda	Alkali Sulfides
Sulfur Pastes, Commercial (as now manufactured)	Sulfur
Tobacco Extracts, Home-made	Tobacco Infusions
Tobacco Juice or Tea	Tobacco Infusions
"Tri-plumbic" Lead Arsenate	Basic Lead Arsenate
Wettable Sulfurs, Commercial (as now manufactured)	Sulfur
Wettable Sulfurs, home-made (containing glue, flour, or dextrin)	Sulfur

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF ENTOMOLOGY.

L. O. HOWARD,
Entomologist and Chief of Bureau.

SOME TIMELY SUGGESTIONS FOR THE OWNERS OF WOODLOTS IN NEW ENGLAND.

BY

F. H. MOSHER, *Entomological Assistant,*

AND

G. E. CLEMENT, *Assistant in Forest Management, Gipsy Moth and Brown-tail Moth Investigations.*

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L. O. Howard, *Entomologist and Chief of Bureau.*

SOME TIMELY SUGGESTIONS FOR THE OWNERS OF WOODLOTS IN NEW ENGLAND.

By F. H. Mosher, *Entomological Assistant*, and G. E. Clement, *Assistant in Forest Management, Gipsy Moth and Brown-tail Moth Investigations.*

Farmers and other woodlot owners in New England have, at the present time, an unusual opportunity not only to realize appreciable sums from their timber but also to better the condition of their woodlands and lessen the liability of their being attacked by the gipsy moth. Because of the increased demand for cordwood it is now possible to dispose of classes of material not ordinarily merchantable, and while labor is scarce and high priced the increased cost of getting out cordwood, it is believed, will be offset by the higher value of the wood. For these reasons timber owners, by puting into effect a few simple rules regarding the handling of their timber, will often be able to accomplish all the following objects at one time:

First. A large amount of low-grade wood can be disposed of to the advantage of the owner.

Second. A better class of trees with improved growing conditions will be provided by the removal of inferior trees now standing.

Third. The numbers of gipsy moths may be reduced by the removal of those trees of which they are particularly fond and upon which they thrive particularly well.

In cutting cordwood heretofore, the practice generally has been to cut clean. Where most of the trees on an area are mature, dead, dying, or defective, a continuation of this practice is to be recommended, but where a large number of young trees are standing it is often preferable to thin judiciously. Such thinning should be based on several considerations, among which are:

1. All dead, dying, and defective trees should be cut to make room for live trees, and in the case of dying trees, to check the development of injurious insects which may breed in them.

2. Species of trees having the highest commercial value should be given every opportunity to grow and develop well. All other trees interfering with their growth and development should be removed.

3. Most trees to grow to the best advantage need a large amount of light. A thinning should aim to space the trees so that each individual shall have a proper amount of light.

4. The foliage of certain species of trees is more desired by gipsy moths than that of other species. The removal of such trees may often afford relief from these pests.

5. The price of lumber is rising, and the value of woods of good quality will rise correspondingly. Thinning may often be a great help in the production of such woods, besides increasing the rate of growth.

6. Cutting clean is injurious to forest soil, and a long time must elapse before another cut can be grown. Since no one can predict how long war conditions will last, it seems advisable to cut gradually, removing the poorest trees first and saving the better ones for higher prices.

There are 75 species of native and naturalized trees growing in this region. Realizing their varying liability to gipsy-moth attack, the Bureau of Entomology has conducted extensive laboratory experiments for a series of years to determine the susceptibility of each of these species. It has been found that the small caterpillars will not feed on certain kinds of foliage, although they may seriously injure the same trees after becoming nearly full grown. Other trees are eaten freely by caterpillars of all sizes, while some foliage is never attacked.

All of the laboratory experiments were supplemented by extensive observations on the feeding of the caterpillars in the field, and from the data secured the forest trees have been grouped in the following classes:

Class I.—*Species that are favored food of gipsy-moth larvæ in all their stages.*

Ash, Mountain.
Aspen.
Aspen, Large-tooth.
Balm of Gilead.
Basswood.
Beech.
Birch, Gray.
Birch, Paper.
Birch, River.
Boxelder.
Oak, Black.
Oak, Bur.
Oak, Chestnut.
Oak, Pin.
Oak, Post.
Oak, Red.
Oak, Scarlet.
Oak, Scrub.
Oak, Swamp white.
Oak, White.
Service Berry.
Sumac, Dwarf.
Sumac, Staghorn.
Tamarack.
Willow, Glaucous.
Witch Hazel.

Class II.—*Species that are favored food for gipsy-moth larvæ after the earlier larva stages.*

Chestnut.
Hemlock.
Pine, Pitch.
Pine, Red.
Pine, White.
Spruce, Black.
Spruce, Red.
Spruce, White.

Class III.—*Species that are not particularly favored, but upon which a small proportion of the gipsy-moth larvæ may develop.*

Beech, Blue.
Birch, Black.
Birch, Yellow.
Cherry, Black.
Cherry, Choke.
Cherry, Wild red.
Cottonwood.
Elm, American.
Elm, Slippery.
Gum, Black.
Hickory, Bitternut.
Hickory, Mocker-nut.
Hickory, Pignut.
Hickory, Shagbark.
Hop Hornbeam.
Maple, Red.
Maple, Silver.
Maple, Sugar.
Poplar, Silver.
Sassafras.

Class IV.—*Species that are unfavored food for gipsy-moth larvæ.*

Arborvitæ.
Ash, Black.
Ash, Red.
Ash, White.
Balsam Fir.
Butternut.
Cedar, Red.
Cedar, White.
Dogwood, Flowering.
Hackberry.
Holly, American.
Laurel, Mountain.
Locust, Black.
Locust, Honey.
Maple, Mountain.
Maple, Striped.
Mulberry, Red.
Sheepberry.
Sycamore.
Tulip.
Walnut, Black.

The gipsy moth is such a serious pest over a large portion of New England that the varying extent to which it feeds on trees of different species is a very important factor in determining what trees shall be removed and what ones preserved in thinning. Other factors affecting such determination are the commercial value, rapidity of growth, and adaptability to different soil conditions of different species of trees. With these several factors and 75 species of trees occurring in a multitude of combinations, it can be seen how impossible it is to outline any plan of thinning which will be applicable in all cases. An attempt is made here, however, to indicate in a general way some of the qualities of each species which must be considered in thinning.

TREATMENT OF TREES IN CLASS I.

Beginning with Class I of the foregoing classification, it is found to be composed of 26 species which are favored as food by gipsy-moth larvæ. Ten of these species, namely, *mountain ash*, *gray birch*, *river birch*, *boxelder*, *scrub oak*, *service berry*, *dwarf sumac*, *staghorn sumac*, *glaucous willow*, and *witch hazel* are of little commercial value and should be removed.

Ten of the species in this class are oaks, including the scrub oak just mentioned. Oaks growing on light soils and rocky ridges are usually not very vigorous, grow slowly, and suffer severely from gipsy-moth attack.

The *bur oak, chestnut oak, pin oak, post oak,* and *swamp white oak* are generally more or less rare and of restricted local occurrence in this region, so that they have no great commercial importance. Owing to their great susceptibility to moth attack these trees should be cut in every case where they are interfering with the growth of better trees, or where there is an opportunity to replace them with trees not so liable to moth attack.

The *white oak* reaches the northern limit of its range in the gipsy-moth infested region, yet it is one of the most abundant of the oaks. Its foliage seems to be particularly desired by the gipsy moth, and it grows very slowly. For these reasons it is not a desirable type for growth in this region.

The *red, black,* and *scarlet oaks* grow well and produce a valuable class of material. Where young, vigorous trees of these species occur on good soil in mixture with other trees, they may be left, despite their liability to gipsy-moth attack, providing that they are not interfering with the growth of more valuable trees.

Aspen, large-tooth aspen, and *balm of Gilead* can not tolerate shade, and they grow well only where they have free access to plenty of light. Scattered specimens in mixed woods may well be cut, but pure stands, which occur occasionally, may be left to mature when they are in demand for pulp or excelsior.

Basswood occurs very much scattered in this region and grows to advantage only on the best of sites. It may well be eliminated from all others.

Beech is more abundant in the northern than in the southern portion of the region. It grows slowly and is likely to become defective before maturity. It is perhaps the least liable to damage by the gipsy moth of any of the Class I trees. It is an excellent fuel and should be cut heavily when in the way of faster growing and more valuable trees.

Paper birch demands a large amount of light to grow well and is not abundant in mixed stands. When it occurs in abundance, it is in good demand for spool and novelty wood. It makes an excellent fuel, and scattered specimens could often be cut to the advantage of trees to be left.

Tamarack is nowhere abundant in the infested region. When dry it makes excellent kindling and a hot fire for a short time.

TREATMENT OF TREES IN CLASS II.

Class II is composed of eight species of trees on which gipsy-moth caterpillars in their earliest stages do not feed, but upon which they do feed in their later stages. Hence, if stands composed of these species have in their vicinity no plants upon which the young caterpillars can feed, the stands may safely be considered immune from attack. Trees of this class may be grown safely in mixture with trees of Class IV.

Stands composed largely of one or more of the species of this class can be made immune from gipsy moth attack by removing the trees which may provide the young larvæ with food. There are many places where a considerable amount of cordwood could be cut most advantageously with this object in view.

Great care should be taken to protect and preserve young *white pine* and *red pine*, especially when they occur on poor soils. They often grow well on such soils, and if they are present the associated hardwoods which do not grow well on such sites, and which may be subject to caterpillar attack, may be cut beneficially. Red pine is not affected by the white-pine blister rust, which is spreading very slowly among the white pines. If young white pines are given a fair chance to grow, they will probably reach maturity before being seriously affected by the rust.

Chestnut grows well and yields a valuable product, but unfortunately is subject to attacks of the chestnut blight. It makes a poor grade of fuel, but with a shortage of the better grades an opportunity doubtless will be afforded for the disposal of a considerable amount of this species.

TREATMENT OF TREES IN CLASS III.

Class III is composed of 20 species which are not particularly favored by gipsy moths, but upon which a small proportion of the larvæ may develop. Stands composed of any trees of this class alone or mixed with trees of Class IV, but containing no trees of Class I, would maintain only slight infestations and rarely, if ever, would be defoliated.

Blue beech, *choke cherry*, *wild red cherry*, *hop hornbeam*, and *sassafras* have no particular commercial value ordinarily and could well be converted into cordwood at this time.

Black cherry has considerable commercial value, but its occurrence is generally rare. *American elm* and *slippery elm* are also generally scattered. Unless growing in very good soil, these trees could well be cut. *Cottonwood*, *bitternut hickory*, *black gum*, *silver maple*, and *silver poplar* are rare. Bitternut hickory makes very good fuel, but silver maple is not so good. The cutting or preservation of these species will have little effect in any respect.

The remaining trees of this class, namely, *black* and *yellow birches*, *mockernut*, *pignut*, and *shagbark hickories*, and *red* and *sugar maples* can be grown in comparative safety as far as the gipsy moth is concerned. The yellow birch, hickories, and sugar maple make the best of fuel, but they also produce excellent grades of lumber. With fuel of this class in great demand, there will be a temptation to cut young trees of this species. Dead, dying, and defective trees may well be removed now, but young and vigorous trees should be left to grow to larger and hence more valuable sizes.

TREATMENT OF TREES IN CLASS IV.

Class IV is composed of 21 species of trees on which the gipsy moth does not feed, or if it does, the amount is so slight as to be entirely negligible. Stands composed of trees of this group alone or combined with trees of Class II need cause no anxiety whatever as far as gipsy-moth attack is concerned. *Flowering dogwood*, *mountain laurel*, *mountain maple*, *striped maple*, and *sheepberry* have little or no commercial value locally, and if large enough could well be cut for cordwood at this time.

Arborvitæ, *black ash*, and *white cedar* occur usually in or near swamps. They need no consideration as fuel.

Butternut, *red cedar*, *locust*, *honey locust*, and *sycamore* all require a large amount of light, for which reason they occur rarely in mixed woods, and they are of little importance as fuel.

Red ash, *hackberry*, *American holly*, *red mulberry*, *tulip*, and *black walnut* are so rare as to require little consideration.

In this region of degenerate woods, cuttings or thinnings among young trees should almost always be made with a view to improving the quality of the trees left, or the future growth. This means that woodland should be kept fully stocked, but not crowded, with vigorous trees of the most valuable species. If inferior trees are cut out, care should be taken to protect seedlings and saplings of better species which may be on the ground, for otherwise, in the case of deciduous trees, sprouts will grow vigorously, and the same old conditions will reappear. When young growth of desirable species is not present, and no provision can be made for introducing better trees, it may often be better to leave the existing stand than to cut it.

It is realized that the foregoing suggestions can serve only in a very general way as a guide for thinning, but it is the desire of the Bureau of Entomology of the United States Department of Agriculture to aid the woodland owners of this region in every possible way, and the writers would be pleased as far as possible to confer with any owner in this region who is seriously interested and will apply to them in person or by letter at Bureau of Entomology office, 964 Main Street, Melrose Highlands, Mass.

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CIRCULAR NO. 30. JANUARY 1918

South Carolina
Agricultural Experiment Station
— OF —
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H. W. BARRE, DIRECTOR.

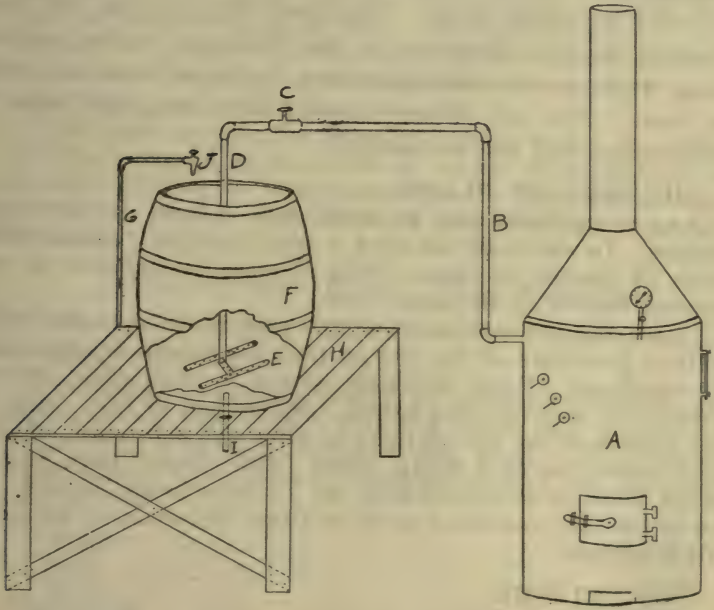

Figure 1—STEAM BOILING PLANT. A. Boiler; B, 1 1-2 inch steam pipe; C, gate valve; D, one inch Steam Pipe; E, "T" from which steam escapes when boiling; F, 50 gallon cocacola barrel; G, water supply pipe; H, platform; this should be about five feet high to make loading easy; I, outlet for Lime Sulphur wash, when done.

Home Made, Steam Boiled, Lime Sulfur Wash.

J. A. BERLY

Lime sulphuur wash is one of the standard winter sprays for scale. A characteristic feature of the wash is that it is fool proof. One may blunder in preparation or application and fail to get the full benefit but there is no danger of injuring the trees when applied during fall, winter or early spring WHEN THE TREES ARE LEAFLESS AND DORMANT. Owing to the difficulties in transportation it may be impossible in many cases to get the Lime Sulfur Wash in time for the winter spray. This could be overcome by purchasing the raw materials in the wholesale market and arrange with some one owning a steam boiler to make the wash at home. This can be very satisfactorily done and often is most convenient and economical.

THE BOILING PLANT.

Any steam boiler may be used, such as gin or saw mill boilers. In our work we used a small upright tubular boiler with 20 pounds of steam. This pressure is sufficient to boil several barrels at the same time.

A one and one half or two inch pipe is fitted to the boiler with a gate-valve at the end so that the escape of steam may be regulated. From the gate-valve a 1 inch pipe extends downward and into the barrel. At the end of this pipe in the bottom of the barrel there is attached a T made of one inch pipes, the ends being closed with caps. Bore 4 to 6 small holes in each branch of the T; these holes should not be in line but scattered so as to allow the steam to escape in all directions.

HOW TO BOIL.

Sulfur	80 pounds.
Lime	40 pounds.

The lime must be not less than 90 per cent pure and this should be specified in ordering.

Put into the barrel about 10 or 12 gallons of water; add the lime, and turn on the steam. When slaking good, add the sulfur, stirring the mixture vigorously with a large paddle. Do not allow the mixture to become dry. When the slaking is over fill the barrel with water to a point 3 inches from the top. Boil as vigorously as possible without overflowing the barrel. The material is strained into another barrel and set aside for future use if not immediately required.

HOW TO DILUTE WITH WATER.

The formula given is the one followed at this station and the wash invariably had a specific gravity of 1.024. To destroy San Jose scale requires a specific gravity of 1.03. The following rule is used. Divide the specific gravity of the boiled wash by the specific gravity required for treatment and the quotient represents the number of dilutions. Example: .1.024 divided by 1.03 equals 8. Therefore the wash is to be diluted 1 part to 8 parts of water. If the specific gravity of the wash is 1.027 the dilution would be 1 to 9.

A simple way to test the specific gravity is by the use of the spray hydrometer, which costs about $1.00. This instrument is provided with a scale. The wash is allowed to cool and the hydrometer is let down in it gently until it floats. The specific gravity then is shown by the figures at the surface of the liquid. The dilution may be marked on the barrel with chalk when stored away.

This wash may be fire boiled. A large kettle is required and there should be an excess of about 10 gallons of water at the beginning to compensate for the loss due to evaporation. This process is much more laborious than when steam is used.

FIRE BOILED WASH—OLD FORMULA.

There are a number of formulas for making this wash, all equally good.

Directions for making should be carefully followed, and a good grade of lime used. This method is used by some who require only a small quantity of the wash. The principal disadvantage is the lack of uniformity, and the necessity of using it fresh.

Sulfur	20 lbs.
Lime	16 lbs.
Water	50 gallons.

Mix the sulfur with a small quantity of water to form a paste, then add it to about 15 gallons of boiling hot water in an iron kettle. Then add the lime slowly and stir constantly. Boil until a greenish yellow or amber color is obtained and all the yellow sulfur has disappeared. Transfer to a 50 gallon spray barrel and fill the barrel with water. It must be used the same day when made.

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COLLEGE OF AGRICULTURE
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THE OLIVE INSECTS OF CALIFORNIA

BY

E. O. ESSIG

BULLETIN No. 283
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Benjamin Ide Wheeler, President of the University.

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THE OLIVE INSECTS OF CALIFORNIA

By E. O. Essig

INTRODUCTION

As compared with other trees in California, the olive is attacked by comparatively few insects and in many localities is almost entirely exempt from regularly destructive pests. The industry, however, is so large and conditions of insect work so varied that it seems advisable to collect all of the available information regarding the insects which infest this crop in one paper. The subject matter is discussed under the two general heads: I, the more important olive insects in California, and II, insects of minor importance to olive trees in California. There is also included at the end a brief discussion of some of the most important olive insects of other states and foreign countries which have not gained access to this state or, as in a few cases, do not attack the olive here.

The writer is specially indebted to Prof. C. W. Woodworth of the Division of Entomology and to Prof. Frederic T. Bioletti of the Division of Viticulture and Enology for many helpful suggestions and corrections.

I. THE MORE IMPORTANT OLIVE INSECTS IN CALIFORNIA

THE BLACK SCALE

Saissetia oleae (Bernard)

Figures 1 and 2

The black scale is the commonest and most troublesome insect pest of the olive in California, but there are many districts which have always been practically free from serious attacks. The young are liable to be killed by hot, dry weather and therefore the insect does not find the climatic conditions of the warmer valleys so favorable to its growth as those along the coast. However, it is gradually encroaching upon territory claimed a few years ago to be absolutely immune because of the hot, dry summers.

In most other states and especially in Europe, this insect is commonly known as the olive scale or olive cochineal and has received the specific name *oleae* from the olive which it commonly attacks. In California, it has always been called the black scale, either because of the dull black color of most of the females or because this insect is the one chiefly responsible for the growth of the black smut fungus over the leaves, stems and fruit of the infested plants. It has one of the most characteristic markings to be found among the scale insects, consisting of a very plain elevated letter ''H'' upon the backs of both the young and old females. The male scales, which are much smaller than the females, are usually entirely wanting and when present appears as very thin, transparently white exuviae, from which the males, after undergoing transformation, emerge as tiny two-winged insects. This occurs when the females are about one-third or half grown. After mating, the males die, and so it is that even when present, because of their small size, entirely different form, and short life, they are not generally known to the orchardists. The females, however, are always in evidence, and do the damage to the trees. They reach maturity in most localities during the months of June, July and August and lay from 100 to 3000 small oblong or oval whitish or amble-colored eggs which remain beneath the large, nearly hemispherical hollow body, the underside of which shrivels as the

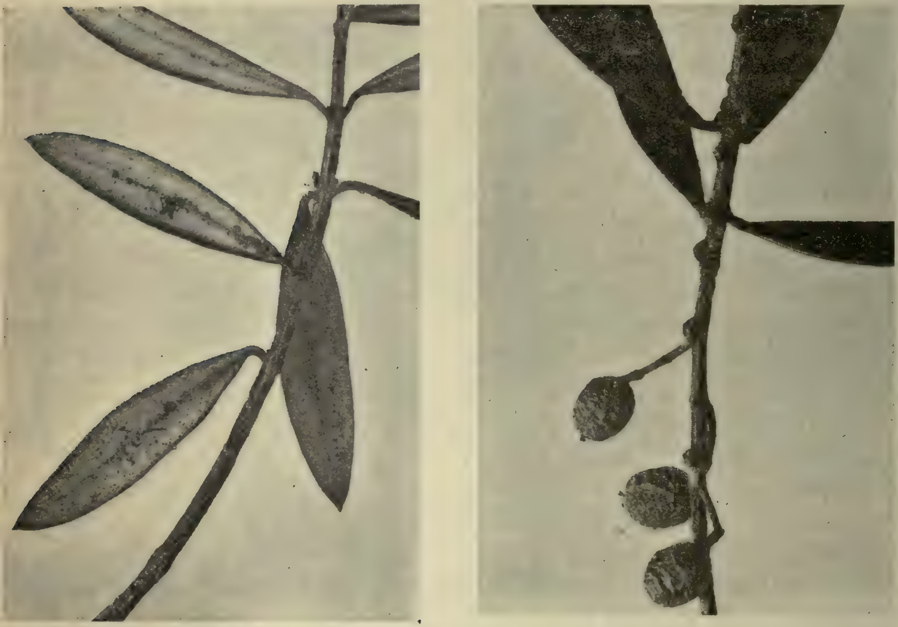

Fig. 1 Fig. 2

Fig. 1.—The black scale, *Saissetia oleae* (Bern.). The young females as they appear on the olive leaves and twigs during the winter months. (Original).

Fig. 2.—Adult females of the black scale, *Saissetia oleae* (Bern.), on an olive twig. (Original.)

(Photos by Div. Sci. Illust., Univ. Calif.)

eggs are laid till scarcely more than a thin shell remains. Upon hatching, the young, which have much endurance for such small creatures, crawl from beneath the bodies of the parents and seek suitable feeding places. The majority first settle on the undersides of the leaves along the midribs while the remainder seek the smaller twigs. Many, of course, perish during the winter, but by spring there are still great numbers remaining, and chiefly those which settled on the twigs. Those on the leaves also move to the twigs and remain there during the rest of their existence or until the old dead bodies fall off. The cold winter months are not conducive to growth, but with the coming of the warm spring days, development is rapid and the excrement, known as honeydew, begins to appear in quantities over the trees. This sweet excrement is the food of a black smut fungus, which, though an after-effect, is the most serious feature about this and many other scale insects. It is the prevention of the smut fungus that most often prompts the control of the black scale. The fungus serves as a good index to the time for spraying.

The black scale is a general feeder and attacks a large and ever-increasing number of plants, the known list for all countries including: almond, *Antidesma,* apple, apricot, mountain ash, aster, beech, buckthorn, camellia, California nutmeg, deodar cedar, *Cestrum,* chrysanthemum, citron, *Duranta,* eucalyptus, fig, fuchsia, geranium, grape, grapefruit, *Grevillea, Grewia,* groundsel tree, guava, English holly, mountain holly or Christmas berry, St. John's wort, jasmine, Irish juniper, laurel, lemon, black locust, honey locust, magnolia, mahogany, maple, *Maytenus, Melaleuca, Myoporum,* nightshade, oleander, olive, orange, trifoliate orange, orchids, palms, periwinkle, pigeon pea, pear, pepper tree, phlox, plum, pomegranate, poplar, privet, prune, rose rubber, sage, sumach, sycamore, tangerine, sago palm, strawberry tree, Thespesia, *Veronica,* and watermelon.

Considering the whole state, very little has been done towards the control of the black scale on olive trees. In a few of the large commercial plantings, particularly along the coast regions, some attention is given to the insect and control measures are employed whenever necessary. These control measures have been well worked out and have given very satisfactory results. In a few instances fumigation has been used in the citrus districts with marked success, but the cost as compared with spraying is so much greater that the latter practice is now almost universally followed where treatments are advantageous. The hardiness and resistance of the olive trees are remarkably great, making it possible to apply very strong sprays without injury to the fruit or foliage. Normally, the dormant sprays for deciduous fruit trees are used, but it is advisable in most cases to reduce their strength about one-fourth to one-third, especially if the fruit is well matured on the trees. The materials used are chiefly oil emulsions, miscible oils and soap powders, although the rosin wash and the distillate-caustic soda-water mixture have also been used with success. The oil emulsions may be prepared at home or purchased from reliable manufacturers. Many growers, realizing the difficulty of securing proper materials for home preparations and the variability of the homemade mixtures, even under the best conditions, prefer to buy manufactured products, especially when only small quantities are needed. For those who desire a homemade product the following formula may be followed for a *crude oil* emulsion:[1]

Crude oil (21° to 24° Baumé)	15 gallons
Liquid soap (or 20 lbs. hard fish oil soap)	3
Water	175

Place the required amount of water in the spray tank and add the liquid soap; agitate thoroughly and pour in the crude oil, continuing the agitation until the mixing is complete and no free oil remains on the surface and also during the application to the trees.

The *distillate-caustic soda-water mixture* is easily prepared as follows:

Distillate (28° Baumé)	7 gallons
Caustic soda (95%)	5 to 7 pounds
Water	to make 200 gallons

First dissolve the caustic soda in a small amount of water and add to the water in the spray tank; begin the agitation and slowly add the distillate, continuing the agitation during the application. This spray will also remove the lichens or moss from the trees.

The *rosin wash* is chiefly used for young and tender nursery stock, because it does not cause the injury often following the application of the previously named materials in such cases. The preparation is:

Rosin	10 pounds
Caustic soda (76% to 95%)	3 to 2½
Fish oil	1½
Water	to make 50 gallons

To a gallon of hot water in an iron kettle add the fish oil and the rosin and heat until the latter is softened; after first dissolving the caustic soda in a small quantity of water add it and stir the mixture thoroughly, after which pour in enough water to make fifty gallons of spray material.

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[1] All of the spray formulae are reduced to meet the average needs for olive trees. They may be strengthened by one-fourth to meet extraordinary conditions.

The *miscible oils* cannot be satisfactorily prepared at home and should be purchased from a reliable manufacturer or dealer and used according to the directions that accompany them.

The oil emulsions, distillate-caustic soda-water mixture and the miscible oils often separate in the spray tank if the water contains much mineral matter and should be applied only with a good power machine with a forceful agitator, which must be kept going during the entire process of application to avoid oil injury to the trees.

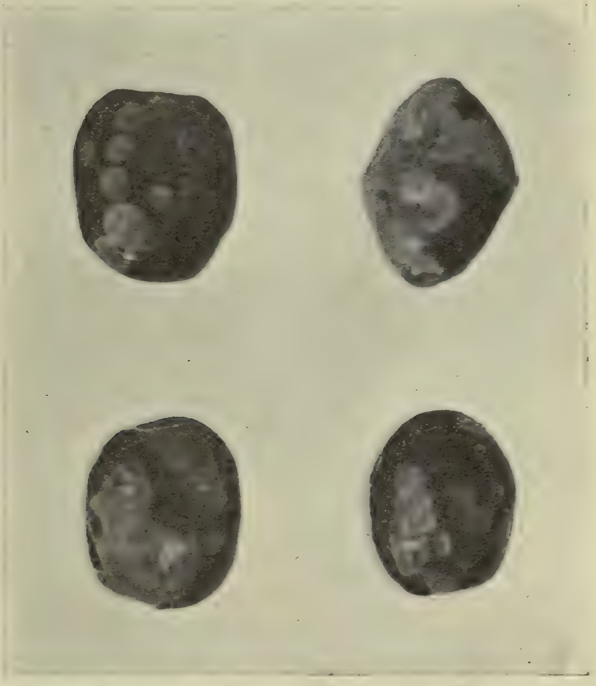

Fig. 3.—The ivy or oleander scale, *Aspidiotus hederae* (Vall.), and its work on the fruit of the olive. (Original.)

(Photo by Div. Sci. Illust., Univ. Calif.)

The *soap powders* are a revival in a somewhat different form of an old spraying material (soap) and in the present form are comparatively new in spraying work and are meeting with much favor because of their comparatively cheapness, ease of handling and efficiency. They are put up in barrels, and are ready to add directly to the water in the spray tank, dissolving readily in cold water with a small amount of stirring or agitation. The average dose is about one pound to every five gallons of water.

The best time to kill the scale is during the period just following hatching, usually in August and September, but fair results may be expected at any time from the middle of August to the first of January.

The proper quantity of material should be applied in the form of a rather coarse driving spray under a pressure of from 100 to 200 pounds. For the average-sized tree from five to seven gallons should be sufficient to thoroughly cover every portion adequately.

A sufficient number of scales to produce any noticeable amount of honeydew and cause a corresponding degree of smutting should be sufficient evidence to warrant spraying.

In spraying an orchard, it is important to keep the following in mind:

1. In case of doubt as to the strength of materials to use, spray a few trees to ascertain results before treating the entire orchard. Allow about two weeks to get the full results of the chemicals.

2. Never spray when the orchard is in need of water, as severe burning of fruit and foliage may result. Irrigate first or wait until after the first rain.

3. Do not spray during excessively hot weather or when hot winds are blowing.

4. Do not spray within several weeks before picking, if possible, as spotting of the fruit may result.

The control of the black scale by natural enemies has long been the subject of much experimental work without any very definite results. True, a number of predaceous and parasitic insects have been introduced to combat it, but their combined efforts are not sufficient to be a reliable factor in the control of the pest in the orchards.

The predaceous insects include the following:[2] the black ladybird beetle, *Rhizobius ventralis* Er., the ashy-gray ladybird beetle, *Olla abdominalis* (Say), *Lindorus lopanthae* (Blaisd.), the steel-blue ladybird beetle, *Orcus chalybeus* (Boisd.) and *Axion plagiatus* Oliv. Of these, the first is the only one of importance. It was first introduced into the olive orchards of Santa Barbara County and has since been distributed generally throughout the state. The larvae and adults feed upon the black scale and in some districts become quite abundant. *Lindorus lopanthae* (Blaisd.) is also quite widely distributed and preys partially upon the black scale. The others seem never to become very numerous or important.

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[2] For a complete list, discussion and illustrations of predaceous and parasitic insects of the black scale, see Bul. 223, Calif. Agr. Exp. Station, July, 1911, by Prof. H. J. Quayle.

Among the parasitic insects, are the scutellista, *Scutellista cyanea* Mots., also known as the African fly, *Dilophogaster californicus* (How.), *Aphycus* sp. and the lecanium parasite, *Coccophagus lecanii* (Fitch). Of these the scutellista is by far the most important and at times becomes remarkably numerous, infesting nearly every egg-laying female of the scale. The larvae feed upon the eggs, but usually leave enough to insure little or no diminution in the number of scales for the next year. Though not at all dependable, it is often relied upon by growers to do what can be accomplished with certainty with sprays, with the result that considerable loss is caused by the omission of control measures every year. The other parasites listed work much more spasmodically and little real investigation has ever been done to ascertain whether they do any good or not.

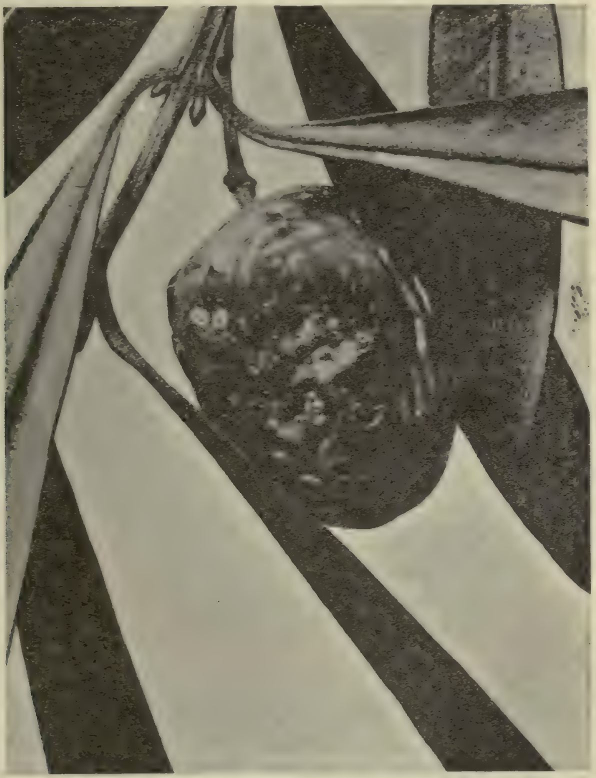

Fig. 4.—The ivy or oleander scale, *Aspidiotus hederae* (Vall.). Adult females and young on an olive. (Original.)

The state insectary is still continuing its endeavors to introduce parasites which will prey more effectively upon the immature stages of the black scale and it is hoped that every success will attend their efforts so as to reduce the expensive operation of spraying.

THE IVY OR OLEANDER SCALE

Aspidiotus hederae (Vallot)

Figures 3–6

In some parts of the San Joaquin and Sacramento valleys, this insect often becomes quite abundant on the leaves, and, in a few instances, on the fruit of the olive trees. In the latter case, it is specially annoying to the growers of ripe pickling olives. The infested fruits become spotted because the retarded development of the tissues around the scales leaves pits or depressions and the checking of the coloring in these places causes them to remain green while the rest of the fruit assumes the natural dark color (fig. 3). The insect gets its common names from the two plants most universally attacked, although in this state others are as commonly infested. It is what is called a true armored scale; that is, the female has over its small, nearly circular, yellow body a protection in the form of a thin gray or whitish circular scale about one-twelfth of an inch in diameter. The scale of the male is more elongated and somewhat smaller, the mature insect being small and winged as in the case of the black scale. In most cases, the scales are scattered over the surface of

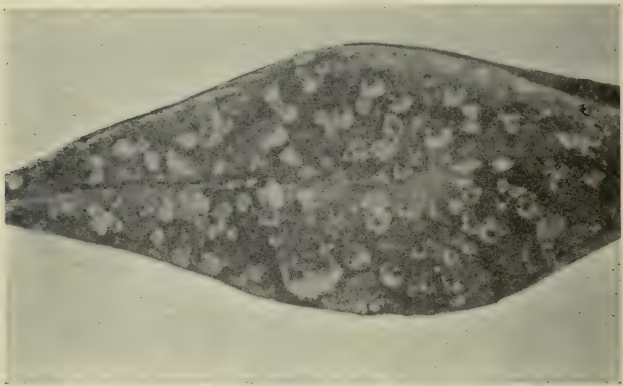

Fig. 5.––The ivy or oleander scale, *Aspidiotus hederae* (Vall.), on an olive leaf. (Original.)

(Photo by Div. Sci. Illust., Univ. Calif.)

the foliage in a very irregular way, while in others they are so thick as to overlap. On the fruit of the olive they occur in small colonies, each group often being composed of a single female and her progeny. The young are born alive and move freely until the first molt, when they lose their legs and must remain throughout the rest of their existence in one spot. Breeding continues almost throughout the entire year in many parts of the state, but it is much more rapid throughout the summer months.

As in the case of the black scale, the list of known food plants is very large and ever increasing, including, in all countries, the following: Acacia, aloe or century plants, asparagus ferns, betel nut, boxwood, buckthorn, butcher's broom, California laurel or pepperwood, cactus, camellia, carob, *Carpodetus serratus,* cherry, citron, clover, currant, daphne, date palms, eucalyptus, fan palms, genista, grapefruit, grasses, *Hakea alliptica*, holly, English ivy, kentia palms, lemon, *Macrozamia*, madder, magnolia, manzanita, maple, mistletoe, Monterey pine, mulberry, *Myrsine retusa,* nightshade, oleander, olive, orange, orchids, oxalis, pepper tree, periwinkle, plum, pomegranate, *Prunus boldus,* holly oak, red-bud, redwood, rubber, sago palm, sumach, umbrella plant, umbrella tree, *Vitex littoralis, Vriesia splendens,* yew and yucca. From this list it will be seen that in-

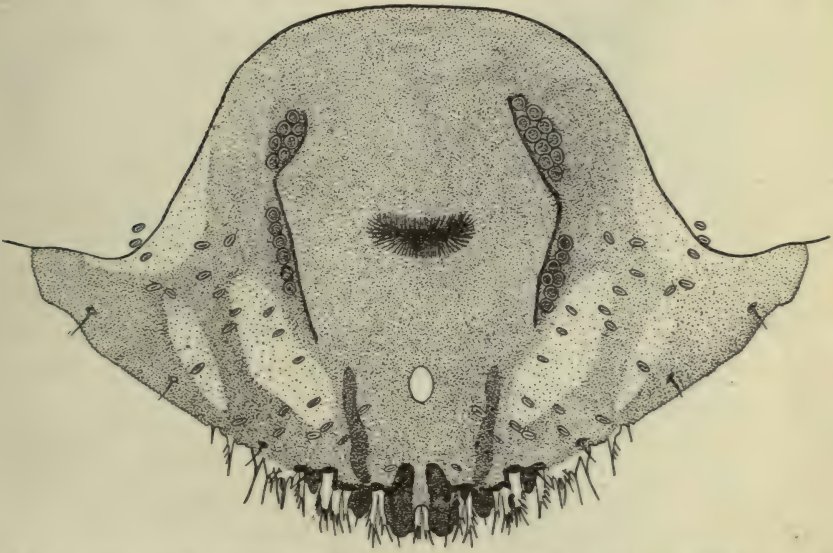

Fig. 6.—The ivy or oleander scale, *Aspidiotus hederae* (Vall.). Drawing of the pygidium of a female. Greatly enlarged. (Original.)

festation may occur from a large number of sources outside the orchards.

The control of this insect is seldom attempted, for the actual loss does not, in most cases, justify the cost of treatment. Where control is desirable the oil emulsion and miscible oil sprays as recommended for the black scale should be used.

Natural enemies have never been considered of any consequence in the control of this scale, although there are both ladybird beetles and hymenopterous parasites that prey upon it in California as elsewhere.

THE BRANCH AND TWIG BORER

Polycaon confertus Leconte

Figure 7

The work of this beetle, which consists of small, round holes from one-eighth to one-fourth of an inch in diameter and usually less than an inch in length at the base of a bud or in the fork of a small branch, is familiar to many orchardists. Occasionally one also finds the beetle itself at work in the holes. It is small, brown and black and about half an inch long. The object of its work is probably to secure food, as no eggs are deposited or young reared in anything but dead wood, while the burrows in orchard trees are always made in perfectly healthy and living tissue. The injury is due to the breaking of the twigs at the holes, and the improper pruning of the trees which results. The young trees suffer most, though old trees are quite as commonly attacked. Plants known to be thus injured are: almond, apple, apricot, cherry, currant, fig, grape, lemon, olive, orange, peach, pear, plum and prune. As previously stated the insect normally breeds in dead wood, chiefly of the madrone, oak, and old grape canes where the larvae may often be found in great numbers.

The beetle occurs generally throughou the state, but has been most annoying in the Sacramento, San Joaquin, and Santa Clara Valleys and the central coast region. The attacks are spasmodic and of short duration and the damage done through a succession of years is really slight. Regular control measures have never been tested out because they are generally unnecessary. The elimination of the dead wood in which the insect breeds might be suggested as a preventive measure and in young orchards, where the attacks are severe, it might be advisable to go over the trees about once a week and kill the beetles in the burrows with a wire or knife blade.

THE OLIVE BARK-BEETLE

Luperisinus californicus Swaine

Figures 8 and 9

Though at present a comparatively unknown insect, this beetle may possibly become one that must be reckoned with in the future, if we are to judge by what little is now known regarding its work. A few adults were first taken by H. A. Weinland, then Horticultural Commissioner of San Diego County, in the Mission Valley near the city of San Diego on May 17, 1915, and forwarded to the writer with the information that they were found injuring a living olive tree and might prove to be a serious pest. Other specimens followed from the same source on May 27 along with a piece of limb showing the work of the beetle and containing, within the burrows, a few cocoons of a hymenopterous parasite. On January 27, 1916, the present Horticultural Commissioner, Mr. H. M. Armitage, sent in a large number of the beetles as well as specimens of their work and a number of the parasites mounted on slides. The insect proved to be new to the university staff and they were forwarded to Mr. J. M. Swaine, Department of Agriculture, Dominion of Canada, a specialist in this

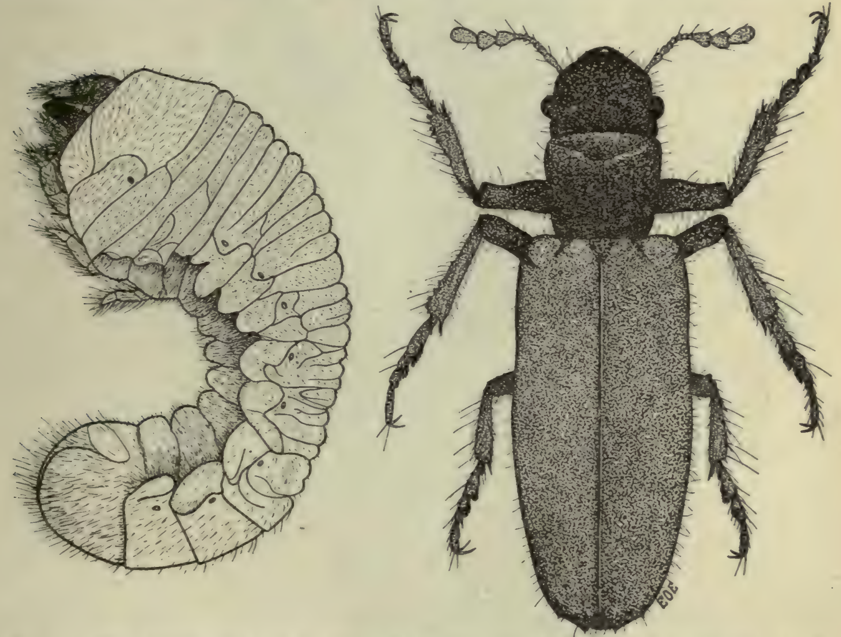

Fig. 7.—The branch and twig borer, *Polycaon confertus* Lec. Larva and adult. Enlarged. (Original.)

family of beetles, who pronounced it a new species and gave it the scientific name, *Luperisinus californicus*.[3] For a common name the writer has proposed the olive bark-beetle, which seems to be sufficiently descriptive.

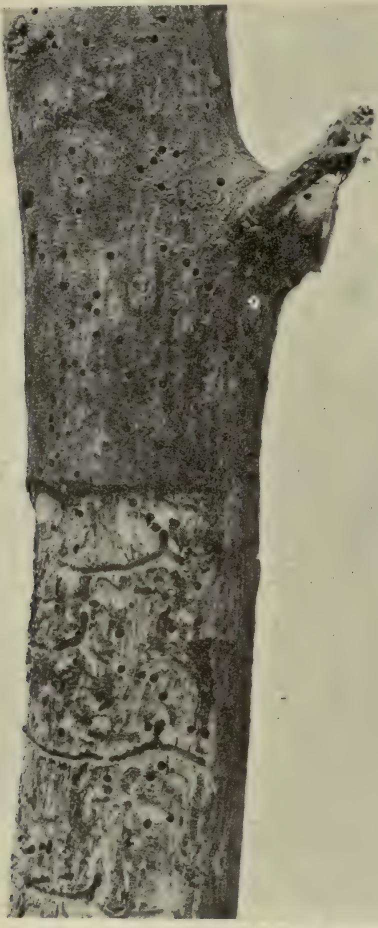

Fig. 8.—The olive bark-beetle, *Luperisinus californicus* Swaine. Work and exit holes made by the larvae and adults on an olive limb. (Original.)

(Photo by Div. Sci. Illust., Univ. Calif.)

The insect is a small, robust beetle about one-eighth of an inch long, black with whitish scales forming a more or less definite pattern on the back, as shown in the drawing (fig. 9). The legs and most of the antennae are reddish and the entire body is covered with small simple and plumose hairs of various sizes. In general shape and size, the adults resemble very closely the fruit-tree bark-beetle, *Eccoptogaster rugulosus* (Ratz.), a common pest to deciduous fruit trees in various parts of the state. The work also resembles that of this beetle and consists in the destruction of the cambium layer by numerous small burrows (fig. 8) which may entirely girdle the infested portions of the trees. The perfectly round entrance and exit holes of the adults through the bark are the only distinct external evidences of the work, excepting the general unhealthy appearance of the infested trees. The insects apparently prefer sickly or dying trees and breed abundantly in them as well as in the dead prunings. However, like many of the orchard bark-beetles, they will not hesitate to attack perfectly vigorous and sound trees in close proximity to their breeding places, especially if an entrance may be gained through a sunburned or wounded spot.

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[3] *Canadian Entomologist*, vol. XLVIII, no. 6, pp. 190–192, June, 1916.

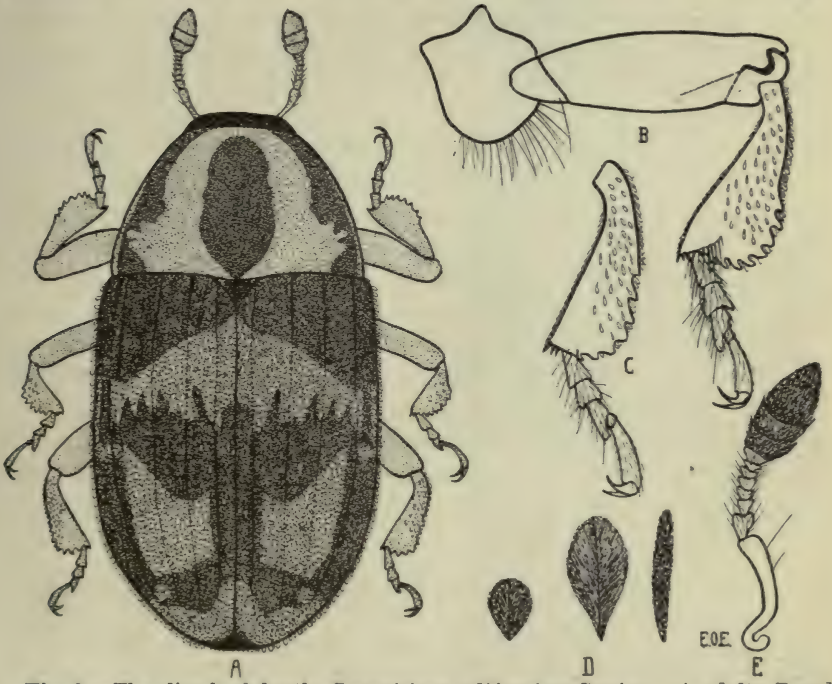

Fig. 9.—The olive bark-beetle, *Luperisinus californicus* Swaine. *A*, adult; *B* and *C*, leg and tarsi; *D*, plumose hairs from body; *E*, antenna. Enlarged. (Original.)

The distribution of the species is not well known. Besides the infestation in San Diego County, already referred to, adults were taken at Camp Greely, Fresno County, as early as 1909 by Mr. Ralph Hopping,[4] but no host plants were recorded, the specimens having been collected in sweepings in the chaparral belt at an elevation of 3000 feet. So far there have been no reports of its attacking olive trees in Fresno County. On July 9, 1916, the writer received a small piece of olive bark from a grower at Bakersfield, Kern County, showing small exit holes exactly like those made by the insect in question, with the statement that the insect causing the injury had badly attacked the young olive trees with the result that one was already dying. The possibilities of its being the same thing are very strong, though no opportunity has been afforded to make a personal investigation.

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[4] *Canadian Entomologist*, vol. XLVIII, no. 6, p. 192, June, 1916.

As in the case of other orchard bark-beetles, the first essential in avoiding attacks is to maintain a healthy condition of all the trees and to prevent sunburn and injuries which lessen their vitality and furnish the proper conditions for the entrance of the beetles. The immediate burning of all prunings is also important, to eliminate possible breeding places around the orchards. After an orchard has become infested, the only effective step is to cut out and burn all infested limbs or trees as soon as discovered, to avoid spreading and continued attacks.

The small hymenopterous parasite[5] which attacks the immature stages within the burrows is not likely to be of much consequence in controlling the beetle.

II. INSECTS OF MINOR IMPORTANCE TO OLIVE TREES IN CALIFORNIA

Of the following insects, it is not likely that any will prove of real economic importance, but they are included because they are sometimes found infesting the olive trees and excite the suspicion of the orchardists.

1. The citrus thrips, *Scirtothrips citri* (Moulton). Taken in the flowers of olive trees in the San Joaquin Valley.[6]

2. The bean thrips, *Heliothrips fasciatus* Pergande. Reported as seriously infesting the fruit of olives in San Joaquin County in 1915.[7]

3. The net-winged cicada, *Platypedia areolata* Uhler. Sometimes punctures the small limbs of the olive to insert its eggs. The punctures cause the twigs to become distorted or to break. The distribution is general throughout the state.

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[5] The parasite has been determined by Mr. Rohwer as *Ecphylus*, probably *schwarzi* Rohwer, through the kindness of Mr. Harry S. Smith, superintendent of the State Insectary.

[6] Jones, P. R. & Horton, J. R., Bull. no. 99, pt. 1, p. 3, Bur. Ent., U. S. Dept. Agr., 1911.

[7] Smith, H. S., Mthly. Bull. Cal. Hort. Com., vol. IV, p. 574, 1915.

4. The mountain-ash louse, *Prociphilus fraxini-dipetalae* (Essig) (fig. 10). This species rarely attacks the olive, having been taken by the writer on the tender sprouts at Berkeley, 1914, and on the leaves at Corning, the same year, by Chas. B. Weeks, Horticultural Commissioner.

5. The red scale, *Chrysomphalus aurantii* (Mask.). A citrus pest reported on olive in the southern part of the state by Prof. H. J. Quayle.[8] It was recently received from Roy K. Bishop, Horticultural Commissioner, who took it on olives in Orange County. The leaves were thickly covered.

6. The purple scale, *Lepidosaphes beckii* (Newm.). Also a citrus pest reported on olives in southern California by Prof. H. J. Quayle.[9]

7. The greedy scale, *Aspidiotus camelliae* Sign. (figs. 11 and 12). Very common on the bark of the branches, especially of old suckers. It may be easily mistaken for the ivy or oleander scale, the color being much the same, but the outside shell is more robust, nearly conical in shape and with the small exuvia or nipple at one side rather than at the middle. The characters of the anal plate, as shown under the microscope (fig. 12) at once separate it from the ivy or oleander scale (fig. 6). Though often abundant, it does not seem to hurt the infested portions in any noticeable way.

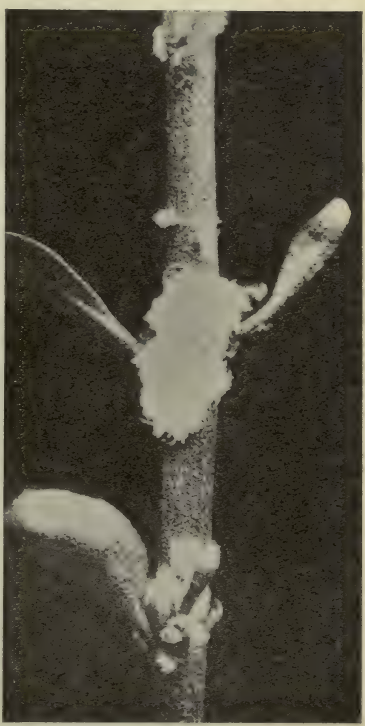

Fig. 10.—Apterous females and young of the mountain ash louse, *Prociphilus fraxini-dipetalae* (Essig), on olive. (Original.)

8. The omnivorous looper, *Sabulodes caberata* Guen. The caterpillars of this moth occasionally feed upon the leaves of the olive trees at Berkeley.

9. The larvae of a moth (Pyralid?) have been taken a number of times from the knots on the olive limbs produced by the bacteria, *Bacterium savastanoi* Smith, by Prof. W. T. Horne and Prof. Elmore Chase at Fairoaks. The soft spongy tissues as well as the

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[8] Bull. 222, Cal. Agr. Exp. Sta., p. 106, 1911.

[9] Bull. 226, Cal. Agr. Exp. Sta., p. 325, 1912.

harder portions of the knots are thoroughly perforated with the burrows (fig. 13) made by the caterpillars. It does not appear to attack any other parts of the trees. The caterpillars are whitish and about one inch long. They are quite abundant, but so far no adults have been reared to determine the species.

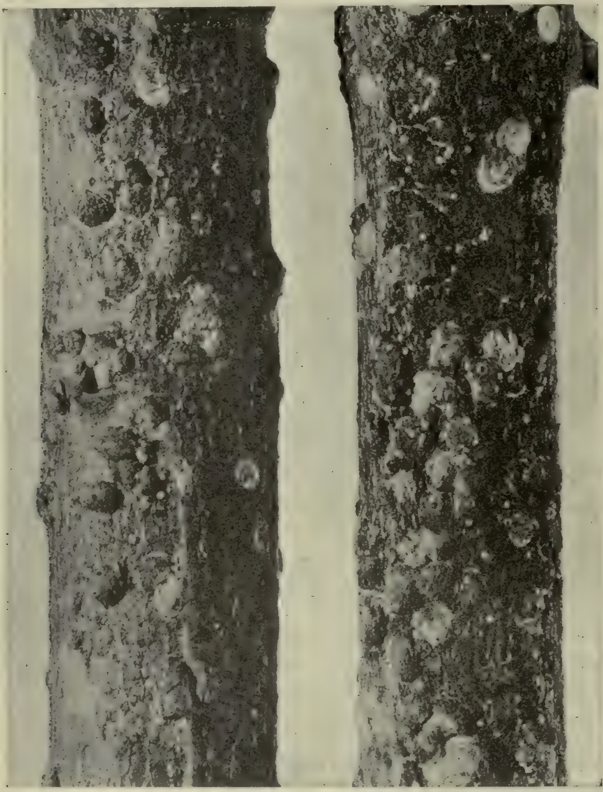

Fig. 11.—The greedy scale, *Aspidiotus camelliae* Sign., on old olive suckers. The smut fungus which partially conceals the scales is from black scale on the same tree. (Original.)

(Photo by Div. Sci. Illust., Univ. Calif.)

SOME OF THE PRINCIPAL INSECTS ATTACKING THE OLIVE TREES IN OTHER STATES AND FOREIGN COUNTRIES

There are but few olives grown in other states of this country, consequently the list of pests on them is very short. In a number of foreign countries, however, and particularly in the Mediterranean region, where the olive has been growing for ages, the number of recorded pests is quite large. Among the many there are but few serious enough to warrant control measures. In the following list the most important ones as well as a number of lesser importance which are most often found in published economic literature, are included so as to give some idea of the difficulties of growing olives in other districts, as well as to reflect the benefit derived from excluding these by state and national quarantine.

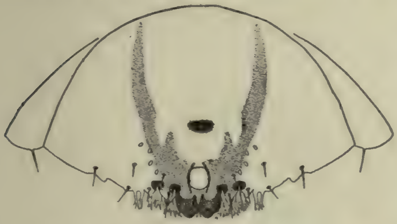

Fig. 12.—Drawing of the pygidium of the greedy scale, *Aspidiotus camelliae* Sign. Greatly enlarged. (Original.)

1. The olive thrips, *Phloeothrips oleae* (Costa) (fig. 14). This insects attacks the leaves and fruit, producing the characteristic scarring common to the thrips. It occurs throughout Southern Europe, Palestine, and South Africa and at times is a serious pest.

2. The cicada, *Tibicen cinctifer* (Uhler). The egg punctures weaken the small twigs and branches of young olive trees in the Salt River Valley, Arizona.[10]

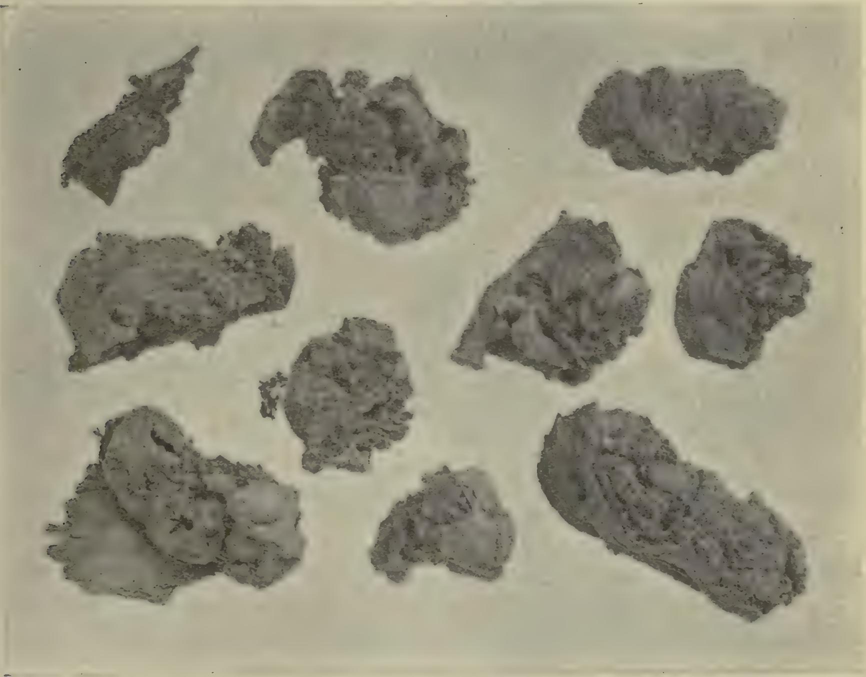

Fig. 13.—Work of a caterpillar on the olive knot at Fairoaks. (Original.)
(Photo by Div. Sci. Illust., Univ. Calif.)

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[10] Morrill, Dr. A. W., 7th Ann. Rept. Com. Agric. and Hort., p. 34, 1915, *Cicada.*

3. The olive psylla, *Euphyllura olivina* (Costa) (fig. 15). This insect infests the young shoots, buds and flowers, causing the latter to drop and prevents the setting of much of the young fruit. The young psyllids are covered with a white cottony material which entirely hides them from view. It occurs throughout southern Europe and in Palestine and is a pest of minor importance except in rare instances.

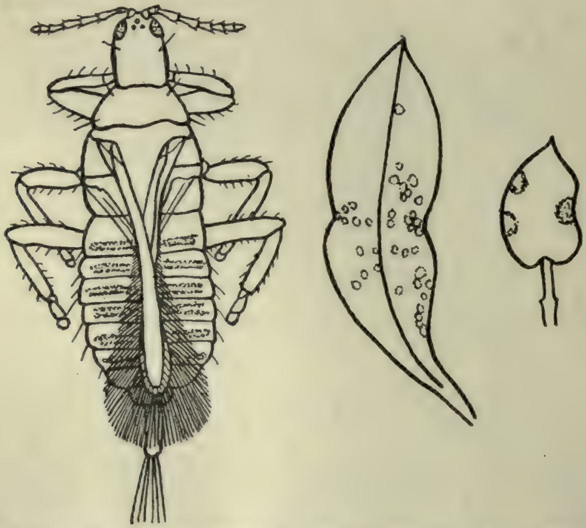

Fig. 14.—The olive thrips, *Phloeothrips oleae* (Costa). Adult female and work of the insect on leaf and fruit of the olive. (Redrawn from Del Guercio.)

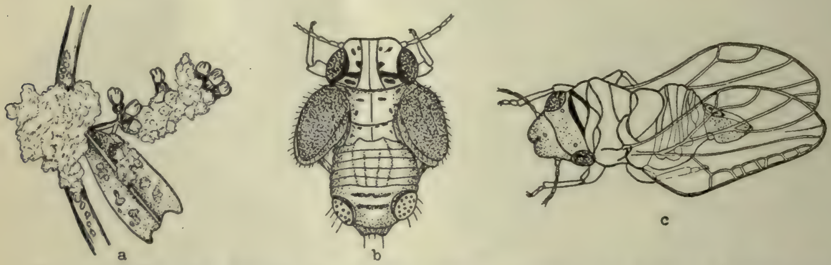

Fig. 15.—The olive psylla, *Euphyllura olivina* (Costa). *a,* colony of young on twig and flowers; *b,* nymph; *c,* adult. (Redrawn from Coutance and Del Guercio.)

4. The scale, *Pollinia pollini* (Costa). A soft scale attacking the smaller branches of the olive trees in southern Europe. It was once taken on a few olive trees at Pasadena, California, which were imported from Italy in 1893. Alexander Craw at once promptly de-

stroyed the infested trees and apparently exterminated the insect.[11] Where found it is a pest of little importance.

5. The scale, *Filippia oleae* (Costa). A soft scale infesting the olive leaves in southern Europe, but not nearly so serious as the black scale, *Saissetia oleae* (Bern.) in the same localities, because it produces little honeydew and causes practically no smutting.

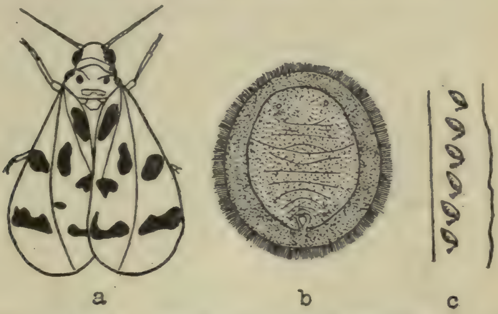

Fig. 16.—The olive white fly, *Aleyrodes olivinus* Silvestri. *a*, adult; *b*, nymph; *c*, row of eggs. (Redrawn from Silvestri.)

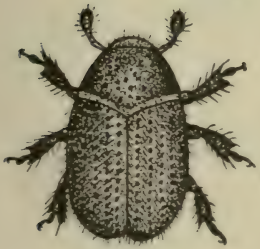

Fig. 17

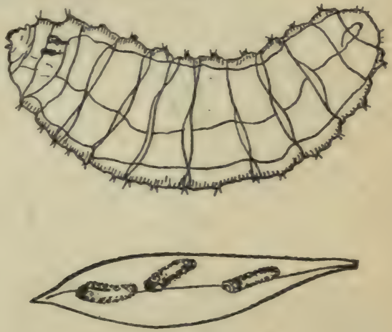

Fig .18

Fig. 17.—Adult of the bark-beetle, *Hylesinus oleiperda* (Fab.). (Redrawn from Barbey.)

Fig. 18.—The olive leaf-miner, *Perrisia oleae* Angelini. Larva and the mines on an olive leaf. (Redrawn from Del Guercio.)

6. The terrapin scale, *Lecanium nigrofasciatum* Pergrande, was reported by Pergrande as occurring on olive in Florida.[12]

7. *Leucaspis riccae* (Targ.). A scale insect commonly attacking olive trees in southern Europe and northern Africa, but of little consequence as a pest.

8. The rufous scale, *Selenaspidis articulatus* (Morgan). A scale occurring in southern Africa, West Indies and at Key West, Florida.

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[11] 4th Bien. Rept. Cal. Bd. Hort., p. 438, 1894, and 5th Bien. Rept. Cal. Bd. Hort., p. 43, 1916.

[12] Bull. 18, N.S., U. S. Dept. Agr., Bur. Ent., p. 26, 1898.

It attacks citrus and olive trees and is of some importance as pest to the former.

9. The masked scale, *Chrysomphalus personatus* (Comst.). Reported by Dr. T. D. A. Cockerell as severely attacking olive trees at Kingston, Jamaica.[13]

10. The black araucaria scale, *Chrysomphalus rossi* (Mask.). There are many reports to the effect that this scale is a serious olive pest of different parts of Australia.[14] It occurs in California on *Araucaria* spp., but has shown no tendency to attack the olive here.

11. The laurel scale, *Aonidia lauri* (Bouché), is reported as seriously attacking olive trees in Chili.[15]

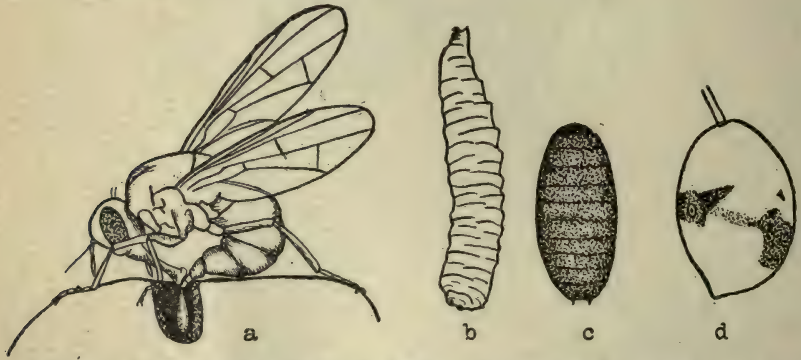

Fig. 19.—The olive fly, *Dacus oleae* Rossi. *a,* adult laying eggs in the fruit of the olive; b, maggot; c, puparium; d, olive showing egg puncture, work and exit hole of the maggot. (Redrawn from Chapelle, Ruby and Martelli.)

12. Glover's scale, *Lepidosaphes gloverii* (Pack.). Also known as the long scale. Attacks the olive in southern France and northern Africa (Tunis). It occurs in San Diego County, where it sparingly attacks citrus trees, but has never been recorded on olive in this state.

13. The scale, *Parlatoria calianthina* Berl. e Leon. Infests the olive in southern Europe. Taken on imported olive trees from Greece in quarantine at San Francisco by inspectors in 1915.[16]

14. The olive white fly, *Aleyrodes olivinus* Silvestri (fig. 16). The nymphs of this insect occur on the leaves of olive trees in central and southern Italy as well as in Spain, Tunis, and Smyrna. It is not a pest of any serious consequence.

15. The bark-beetle, *Hylesinus oleiperda* (Fab.) (fig. 17). This

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[13] *Insect Life,* vol. V, p. 121, Nov., 1892.

[14] French, C., Handb. Destr. Ins. Victoria, pt. II, p. 50, 1893, and Despeissis, A., Handb. Hort. and Vit., 2nd ed., p. 576, 1903.

[15] Philippi, Dr. R. A., *Insect Life,* vol. I, p. 154, Nov., 1888.

[16] Maskew, Frederick, Mthly. Bul. Calif. Hort. Com., vol. V, p. 75, 1916.

beetle causes considerable damage in southern Europe by burrowing into the older portions and the limbs of the olive trees. It is, however, primarily a pest of unhealthy or injured trees.

16. *Phloeotribus scarabaeoides* Bern. (Syn. *P. oleae* Fabr.). Another bark-beetle which makes galleries in the branches and cuts off the small twigs by its burrows. It is a serious pest in Italy. This and the preceding beetle are closely related to the olive bark-beetle recently discovered in California and discussed in this paper.

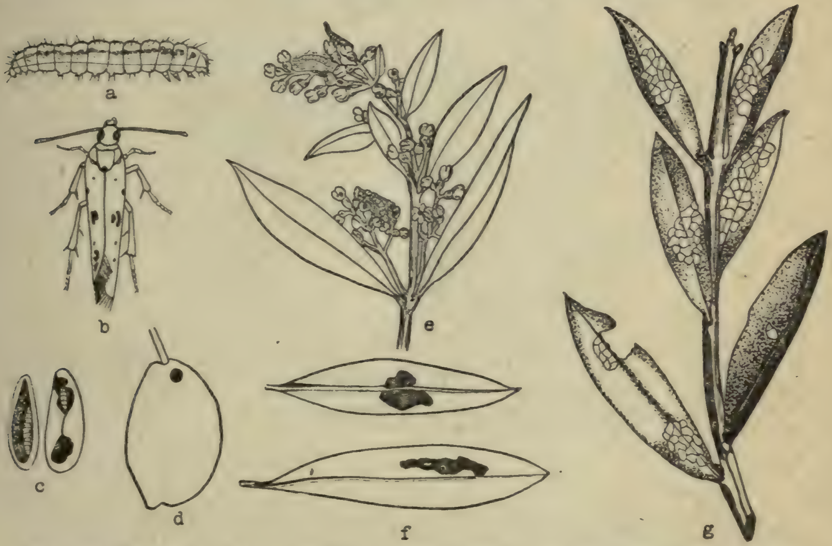

Fig. 20.—The olive tinea, *Prays oleellus* (Fab.). *a,* caterpillar; *b,* adult; *c,* work of caterpillars in seeds; *d,* exit hole of the caterpillar in a fruit; *e,* webs and work of caterpillars on buds and blossoms; *f* and *g,* work of the caterpillars on the leaves of the olive. (Redrawn from Chapelle, Ruby, and Del Guercio.)

17. The olive weevil, *Rhynchites ruber* Fairm. The adults feed upon the tender leaves and tips of the young shoots and puncture the young fruit. The larvae live in the seeds. It does serious damage at times to the olive crop in Italy.

18. The olive leaf-miner, *Perrisia oleae* Angelini (fig. 18). A small cecidomyiid fly the maggots of which mine the leaves of the olive trees in Italy. It is of little economic importance as a pest.

19. The olive fly, *Dacus oleae* Rossi (fig. 19). This is undoubtedly the most serious pest of the olive to be found anywhere and it is very fortunate that it has never gained access to this state. It occurs in the olive-growing sections of southern Europe, Asiatic Turkey, Palestine and northern and southern Africa. The fly punctures the fruit in which it deposits its eggs and within which the larvae

or maggots live until mature. The work of the maggots results in the premature dropping of the fruit and a diminution in the yield of oil. Considerable money is spent annually by the olive growers in the control of this pest.

20. The olive tinea, *Prays oleellus* (Fab.) (fig. 20). This small moth is quite a serious pest in southern Europe and of less importance in Palestine. The caterpillars feed upon the buds, blossoms, and in the seeds of the fruit causing much loss in many cases. It is probably second in importance to the olive fly.

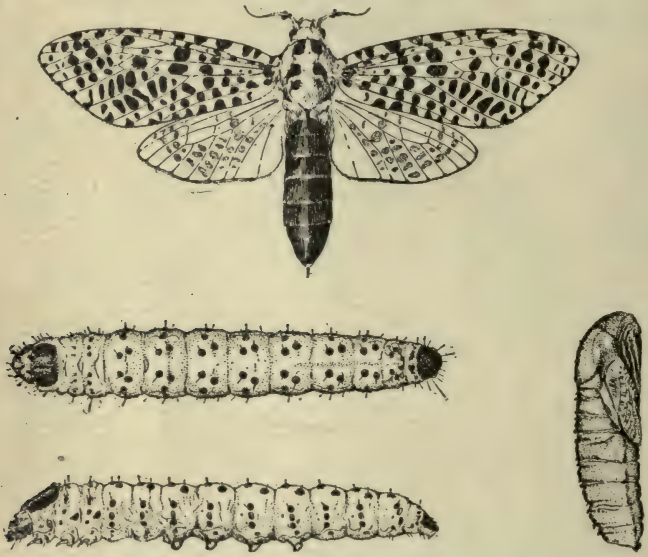

Fig. 21.—The leopard moth, *Zeuzera pyrina* (Linn.). Adult female, caterpillars and chrysalis. Natural size. (After Britton.)

21. The leopard moth, *Zeuzera pyrina* (Linn.) (fig. 21). The caterpillars of this moth bore large galleries into the wood of perfectly sound and healthy trees and do considerable damage to olive trees in southern Europe, especially in Italy. It is reported as the most serious olive pest in Palestine. It also occurs in northern and southern Africa and in Korea, Japan, and along the Atlantic seaboard from Massachusetts to the southern part of New Jersey. The insect is a very destructive pest to a large number of shade and forest trees, as well as to such cultivated fruits as apple, cherry, currant, pear, plum, and walnut. It is an insect that we might well take extra precautions to keep out of California by quarantine or other measures.[17]

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[17] See Farmers' Bull. 708, U. S. Dept. Agr., Feb., 1916, Howard and Chittenden, and Bull. 169, Conn. Agr. Exp. Sta., Nov., 1911, by Britton and Cromie.

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BULLETIN NO. 139 APRIL, 1907

ALABAMA
Agricultural Experiment Station
OF THE
Alabama Polytechnic Institute,
AUBURN.

INJURIOUS INSECTS AND THEIR CONTROL.

BY

WARREN T. CLARKE,

Entomologist

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1907.

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INJURIOUS INSECTS AND THEIR CONTROL.

By

Warren T. Clarke.

The agriculturist, no matter what crop he may be interested in, usually finds that he has to take into account and overcome, if may be, the ravages of insect pests. Sooner or later the question of means of control is sure to present itself to him, and on the solving of this question will depend the possible profit or loss in his farm operations. An intelligent knowledge of the fundamental principles governing the study of insect pests and an acquaintance with the best and most economical ways of applying these principles becomes therefore each day more necessary. The orchardist, the grower of field crops, the truck gardener, each of these must, to a certain extent, work out the problem in his own environment. The fact recognized that some insect is destroying entirely, or greatly reducing, the value of his crop is not sufficient knowledge upon which to base remedial measures. An acquaintance with the way in which the insect makes the damaging attack is necessary, and then the general character of the remedy to be used under these observed conditions must be known for effective work to be done.

It is not in the intention nor scope of the present Bulletin to give a complete treatise on the injurious insects of this state nor to lay down rules of procedure that will be entirely applicable in every case of damage that may arise. Indeed, there are questions in the control of certain insect pests that are today not solved, so we can only at present call attention to well known principles of procedure in such cases. On the other hand, there are many such questions that have received, either here or elsewhere, an adequate answer, and, in a brief way, we may call attention to certain such specific cases.

METHOD OF INJURY.

The injury done by insects to cultivated crops may, for the present and in a general way, be considered as resulting from the insect's effort to get food. There are, undoubtedly, injurious effects to the plant frequently accompanying this food-getting effort that cause more damage to it than can be laid to the mere loss of material taken by the insect. However, the primary damage, from which these other causes of loss spring, is done by the insect in feeding upon the plant. It therefore becomes of importance to know just how the insect feeds, so that the character of the damage may be understood and further, that economical and practical means of control may be applied. The insect's method of eating largely determines the character of the control means to be used. Insects feed upon plants in one of two ways, and on these feeding methods the whole series of injurious insects can be divided into two great groups. Either the insect that is causing damage to our crops has *biting mouth parts* and obtains its food by eating out portions of the attacked plant, from the fruit, the leaves, the branches and trunk, or from the roots, or it has *sucking mouth parts* and obtains its food by piercing the tissue of the part of the plant attacked, and sucking the sap. These two very different methods of feeding are readily recognizable. The work of the leaf eating caterpillars, cut-worms; the damage caused by certain leaf attacking beetles; the feeding marks of grasshoppers upon twigs and branches; the gnawing out done by mole crickets in Irish potatoes; the burrowings and minings of various borers; these forms of damage are characteristic of the work of insects with biting mouth parts. It does not require a high degree of expert knowledge to determine the facts as to eating methods in such cases as these, yet on these facts will depend, in large measure, the method of control most likely to be effective. On the other hand, we shall find that the method of attack of the insects with sucking mouth parts is quite as characteristic and easily recognized.

Poisoning.

If we determine that the insect in which we are interested, is of the biting type, devouring foliage, perhaps, then we know that it actually takes in particles of the plant as food, and we can infer that if poison is placed on this foliage it will become a part of the insect's diet and cause its death. On this determination will depend our use of such poisons as Paris green, arsenate of lead and similar toxic agents. These are known as internal or stomach poisons, are effective only when taken into the digestive tract, and do not trouble the generality of insects when in contact with them externally.

Spraying With Paris Green.—Paris green is an insoluble compound of arsenic and copper, and has received more attention and use in farm practice than has any other arsenical. If properly prepared it should carry but an extremely small percentage of free arsenic, and under these conditions it is generally not injurious to foliage, while being a very effective insecticide. It may be used as a spray in water or may be dusted on the plants or trees to be protected. When used as a spray the mixture should be made as follows:

Paris green	1 pound
Stone lime	4 pounds
Water	200 gallons

Mix the Paris green to a paste in a small quantity of water and then put in the spray tank with nearly the total amount of water to be used. Slack the lime in enough water to break it down completely, being careful, however, not to use enough water to "drown" it. Strain the milk of lime thus obtained through a sieve into the spray tank. Keep the whole mixture thoroughly and constantly stirred while spraying. In using this material as a spray, care must be exercised not to put too much upon the tree to be protected. While enough should be sprayed on to cover the leaves and fruit with a film of the material, if the operation is continued beyond this point and dripping ensues, the leaf edges, and occasionally the entire leaf, will be destroyed by what may be termed arsenical burning. This is caused by an excessive amount of the arsenical being deposited where the running together and dripping occurs.

Dusting Paris Green.—Paris green is also used successfully in certain cases by dusting it upon the plant. This method is especially to be recommended where low growing plants, such as Irish potatoes, are to be protected from leaf-eating insects. When the dusting method is employed the poison should be mixed with some diluting material, such as hydrated lime (lime dust) flour or even fine roadside dust. The poison should be used in not greater quantity than four pounds of Paris green to fifty pounds of the dilutant and generally one half this strength will be found effective. The mixture can be successfully and economically applied to such low growing plants by placing it in a bag made of some loosely woven material and then shaking the bag over the plant that we desire to protect. The work should be done in the early morning while the plants are yet wet with dew so that the poison will stick to them. This is of course a primitive way to distribute poisons in the dust form but there are very effective dusting machines made and obtainable by those who desire more up to date appliances.

Arsenate of lead.—The arsenate of lead is also an insoluble arsenic compound and in the matter of possible damage to foliage is rather to be preferred over the Paris green. It is slightly more expensive than the latter material but requires no lime for its preparation and, when fresh, is somewhat easier to mix with water than is Paris green. It can be used as a spray at the rate of one and one half pounds arsenate of lead to one hundred gallons of water. At this rate its insecticidal value is good. Arsenate of lead is sold under various trade names and is commercially prepared for spraying purposes. It is not made in a dry form and cannot be used in the dusting method.

Poisoned Baits.—The use of arsenicals either as a spray or in the dust form is to be recommended then, in the majority of cases where the injury is distinctly caused by some leaf or twig eating insect with biting mouth parts. There are, however, exceptional cases where neither the dusting nor the spraying method will answer the purpose satisfactorily. This is especially true where so-called "cut-worms," larvæ of certain moths, are causing the damage. When our problem is the control of these insects in vegetable patches or truck gardens, then the most satisfactory results will be obtained by what are known as "poisoned baits." These depend for their killing principle upon either ordinary white arsenic or upon some one of the arsenical compounds as Paris green, London purple, or lead arsenate mixed with or put upon some food that is especially liked by the insects in question.

A quite effective poisoned bait may be made by dipping succulent leaves, such as cabbage leaves, in water in which either arsenic or some arsenic compound has been placed. The amount of the arsenical used may vary quite largely and the result still be satisfactory.

The writer has found the following proportions effective: One quarter pound white arsenic, or one half pound Paris green, to five gallons of water. The mixture should be kept well stirred and the leaves to be poisoned dipped in it. These leaves should then be placed on the ground near the plants to be protected. The work should preferably be done in the late afternoon for usually cut-worms feed in the evening and at night, and the bait will be more attractive to them when fresh. When such succulent leaves are easily obtained in quantity, the method above outlined is recommended.

In many instances, however, such leaves cannot be obtained and when this is the case a poisoned bait made as follows will be found to be thoroughly satisfactory:

Bran	40 pounds
Molasses	2 or 3 gallons
Arsenic (powdered white)	3 pounds

Water .... 5 or 6 gallons

Mix the bran and arsenic together thoroughly while dry so that the poison will be well distributed in the whole mass. Add the molasses, mixing it and the poisoned bran well together. To this add enough water to make a fairly consistent mash. When a handful of the material will hold together in a ball, not too stiffly, enough water will have been added. Spread this bait about in small heaps near the plants that are to be protected. Usually cutworms will feed rather greedily upon this material and their destruction ensues. This bait can be freshened by sprinkling a little water upon it as it lies on the ground. If Paris green is used instead of arsenic the weight of the former poison should be *five* pounds in the formula.

Caution.—Care should be exercised in all instances where arsenic or any of its compounds are used for insecticidal purposes. Domestic animals, cows, horses, swine, hens, turkeys, geese, etc., should not be allowed to feed or browse where these poisons are used. The materials should not be left where human beings might accidentally obtain a poisonous dose. No danger to human beings exists when the arsenic compounds are properly used as a spray to protect fruit or trees from insect ravages. The amount of the poison present on sprayed fruit is usually too small to constitute a dangerous factor. Obviously, no possible danger can exist so far as the edible product is concerned when poisoned baits are used.

MECHANICAL METHODS OF DESTROYING INSECT PESTS.

The use of poison sprays and baits, while generally valuable in the control of insects with biting mouth parts, is not effective in all such cases that may arise. When we have to deal with insects of this type, but which feed upon the internal parts of the plant, the use of these poisons is of no value inasmuch as it is impossible to place the poison in the situation where the insect is feeding. This restriction applies mainly to those insects known as "borers," the most destructive representative of which class that we have to deal with in this state being the well known Peach Tree Borer. Where our problem consists of an attempt to control such pests as these, then mechanical means, so far as our present definite knowledge goes, must be resorted to. Using the insect just referred to, the Peach-Tree Borer, as representing this class of insects the mechanical means to be used, resolve themselves, finally to the actual cutting out and destruction of the individual insects. This may be accomplished by the use of very primitive tools, a good strong knife, indeed, doing effective work when properly handled or more elaborate implements may be employed. The so-called "Porter Hook," invented by Mr. C. M. Porter, of Douglas, Ga.,will be found to be one of the most effective of "worming" tools. It consists essentially of a handle some twelve inches in length into which is firmly set a curved or "hook" blade. This blade is about six inches in length, not including the shank which is inset in the handle, and is well curved so that the straight distance from base of handle to point of blade is four and one half inches. The destruction, by mechanical means, of the borers being here considered can best be done in the fall or early winter. "The larvae are at this time—some eighty-odd per cent. of them—extremely small, and are, for the most part, still on the outside of the tree feeding on such tender spots as they may have located between the ridges and crevices of the bark, and generally involved in a mass of gum and excreta. This, and most of the larvae with it, may be cleaned away by a few rapid sweeps with a steel hook" (i.e., the Porter hook or some similar implement). "The mass of gum, with its content of wriggling caterpillar life, should be thrown or jerked from the hook to a distance of several feet from the tree, in order that the larvae may find it difficult to return and be subjected to capture by predatory agencies. The process of "worming" thus executed is most expeditious and economical and may be conducted on an extensive scale with most satisfactory results."*

Whatever mechanical means may be employed for the destruction of this or other borers, care must be exercised by the operator not to excessively wound or cut the tree. As much damage may be done the tree by careless or inefficient manipulation as would have been done by the borers that may have been destroyed in the operation.

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*Georgia Experiment Station Bulletin 73.

The time above given and the method of work outlined does not, of course, apply to all the various species of borers attacking the different growths in which we may be interested. The general statement, however, may here be repeated that the work of control resolves itself into the careful cutting out, or probing for, the borer and the destruction of the individual pests and we may further emphasize the fact that the use of the arsenical poisons in such cases offers small hope of any success.

Certain injurious insects, notably the plum (or peach) curculio (*Conotrachelus nenuphar* Herbst.), have a habit of dropping to the ground and feigning death when disturbed. This habit is taken advantage of to destroy the insect. Sheets of cloth, upon light wooden frames, are placed beneath the affected trees which are then rather violently shaken or jarred. The disturbed insects fall on to the sheets and are collected from these and destroyed. The work should be done in the early morning when the insects are least active. The jarring process to be at all successful must be begun as soon as the insects are first noted upon the trees and fruit and must be continued until jarring fails to bring down enough to pay for the labor involved. This purely mechanical means of destroying these pests while being fairly satisfactory, so far as it goes, does not fully answer the question of their control. The writer has had occasion to note quite satisfactory results in controlling this pest by *spraying*. In the instance in question, the peach orchard was being sprayed with Bordeaux mixture to control the "brown rot" (Monilia fructigena.) The Bordeaux mixture was properly made by dissolving four pounds of copper sulphate (bluestone) in twenty gallons of water and by carefully slacking five pounds of clean stone lime and stirring the milk of lime or lime paste thus obtained in twenty gallons of water. The copper sulphate solution and the lime water mixture were then poured together through a strainer into the spray tank and to the resulting Bordeaux mixture was added one pound of lead arsenate dissolved in a small quantity of water. The whole mixture was kept thoroughly stirred while being sprayed on the trees.

In the case noted this operation of spraying was repeated three times during the season and mainly to control the "brown-rot." The first application was made just before the blossoms opened and no poison added to the mixture; the second application, this time with the poison added, was made when the fruit had set, while a third application, again with poison, was made some three weeks later. The control obtained indicated considerable value in the method as above outlined. This spraying method of control, however, cannot as yet, be considered as superceding the method of mechanical control of the series of insects now being considered and until further data is at hand jarring for the curculio is the practice to be recommended.

The two methods of mechanical control of insect pests outlined in the preceding paragraphs, that is the destruction by individuals of borers and the shaking down and destroying in numbers such insects as the curculio, indicate lines of work that may have to be employed in certain specific cases. Necessarily the method of work employed will be governed by a study of the insect itself and its habits of life.

TRAP CROPS.

While the methods of work heretofore outlined offer means of control for many insect pests, when these methods have been adapted to the local conditions where the work is to be done, yet there are certain insects that cannot be reached by any of the ways noted. Such of our truck gardeners as are interested in the production of early tomatoes know the damage done by worms to the "bottom" or earliest crop of this vegetable. When this portion of the crop can be brought off uninjured the largest profit accrues to the grower.

The insect causing the greatest part of the loss to this portion of the tomato crop in this state, is the larval or caterpillar form of a moth scientifically known as *Heliothis obsoleta.* In the caterpillar form it is best known as the boll worm of cotton or as the corn worm. It is a destructive enemy of corn and especially of sweet corn and seems to prefer this latter to any other diet. The appearance of the larva or "worm" is familiar to all who have handled sweet corn "in the ear." This food preference can be successfully taken advantage of to control this pest in tomato fields where the saving of the "bottom" crop is a matter of importance, by planting sweet corn as a trap crop. The method to be used is as follows: Prepare the land fully four weeks before the tomato plants are to be removed from the frame and put out in the field. As soon as the land is prepared plant rows of sweet corn about twenty feet apart across the field. The corn should be planted in hills in the rows, these hills being a convenient distance apart for cultivating, so that they may not interfere with this operation after the tomatoes are set out. The sweet corn should be well up and growing before the tomatoes are placed in the field. The adult moth laying the eggs from which are produced the damage causing "worms" are attracted by the sweet corn and oviposit upon it and the tomatoes, in very large measure, escape injury. Of course no paying crop of corn need be expected under these conditions for the product will be too "wormy" to market. It will, however, have well served its purpose as a trap crop and can, at the proper time, be cut for fodder.

This "trap crop" method of controlling certain pests that are not controllable in any other way, deserves study and use upon the part of the truck gardener. It is, however, not to be considered as offering a ready means of relief in every case of insect injury that may arise.

FARM PRACTICE.

Closely related to the "trap crop" method of control of certain insect pests, in a method that may be designated under the rather broad title of "farm practice." There are some insects which, owing to the fact that their place and way of feeding does not admit of it, cannot be well controlled by any of the methods outlined in the previous paragraphs. In certain such cases a study of the life history of the injurious insect indicates that by changes in our time of planting and method of work we can bring on the crop before or after, as the case may be, the pest is most active and hurtful. By this means, though the insects are not destroyed, we avoid the damage that might otherwise be great. One of the insects causing damage to corn in this state is commonly known as the "bud worm." This is the larval form of a beetle known scientifically as *Diabrotica* 12-*punctata*. This beetle is about one quarter inch in length, is yellowish-green in color, with the wing covers marked with twelve black spots. The head and the greater part of the legs is black. It is very fond of cucurbits and is frequently found in numbers on the blossoms of such plants as cucumbers and squashes. The larva ("bud worm") is white or yellowish in color, quite slender and soft bodied. It usually feeds upon the corn roots, though, as it grows older, it may eat directly into the stalk and destroy the plant. It is from this last form of attack that it has received the name, "bud worm." It has been noted that early planted corn is most likely to suffer from the attack of this pest. The method of farm practice suggested by this fact is obviously then *plant as late as possible* to avoid this injury by the "bud worm." In this connection it is as well to say that late planting will not entirely do away with this pest. A system of rotation of crops is highly desirable where this insect is present. This rotation should not include beans or cucurbits as both of these are acceptable food for the Diabrotica. Cotton may be used in the rotation with safety. There are undoubtedly many insect pests now present in our state whose damaging work would be much lessened by some such simple change in practice as that just noted. Where the method would be applicable, however, would be a matter to be determined by the study of individual cases.

Under this heading of "farm practice" we wish to call especial attention to an insect that will in the course of three or four years be of immense importance to the cotton growers of the state. Reference is here made to the Mexican Cotton Boll Weevil, an insect which has not yet made its appearance in Alabama, but whose arrival can be predicted with a fair degree of certainty. While the exact date of the introduction of this pest to this country is not known, yet it must have come here a short time before the year 1894, when the attention of the Bureau of Entomology of the U. S. Department of Agriculture was first called to it. It was then present and harmful to cotton in some seven or eight counties of Texas. Since that time, in spite of all control efforts, it has spread over a larger and larger territory until now the limit of its eastern dispersion is within thirty miles of the Mississippi river. Besides the enormous loss to the cotton crops in the states at present most affected by this pest, Texas and Louisiana, many thousands of dollars have been spent by these states and by the Bureau of Entomology in studies of the insect and in devising ways and means of control. These studies have developed, among other important items, the fact that the Mexican Cotton Boll Weevil hibernates as an adult. This means that a certain proportion of the full grown weevils live in the cotton fields, or in adjacent situations, through the winter and from these overwintering individuals are produced the first of the new series of weevils the following spring. A further important fact is that this weevil is confined to the cotton for its food. Based on these two facts is the method of control of this pest that has proved most satisfactory and it is one of "farm practice" purely. The method is in brief, as follows: First, plant as early as can be and avoid possible frost injury, using seed of some early maturing variety of cotton. Second, by thorough cultivation and the use of fertilizers force the cotton to early maturity. Third, as soon as the crop is made remove by cutting out, raking to windrows and burning, all cotton plants. While this procedure involves a change in practice in cotton growing in this state yet it is a change that would benefit the industry were the Boll Weevil never to get here.

By this method an excessively long period of time results in which no cotton is available as food for the weevils and the number successfully hibernating is much reduced. It is not in the intention of this bulletin to enter very deeply into the subject of the Mexican Cotton Boll Weevil. It is sufficient for our present purpose to merely call attention to the great importance of the method of "farm practice" as applied in this and similar cases of insect attack where other methods offer scanty or no relief.

INSECTS WITH SUCKING MOUTH PARTS.

Our attention so far has been drawn to the insects that have biting mouth parts and that obtain their food by actually eating out portions of the attacked fruit or plant. There is, as was noted in our opening paragraphs, a series of insect pests whose method of eating is quite distinct and different from these so far spoken of. These insects have mouth parts so adapted, structurally, that they pierce through the outer covering of the plant or fruit attacked, and suck out the sap or juice. They do not use as food any of the outer part of the plant and as a consequence none of the poisoning methods heretofore spoken of are of any avail in their control. Another point of dissimilarity between these insects and the group designated as having biting mouth parts is that while the latter insects move about from place to place and do not, as a rule, gather together in fixed colcnies, the series with sucking mouth parts have this bunching together, greg ious habit, strongly developed. Not only is the colonizing habit characteristic of these insects but in the most injurious representatives of the group we find that when the sucking mouth parts have been inserted in the plant tissue and feeding begun the individuals remain fixed in the chosen situation throughout the balance of their lives. This habit of restricted motility, as it may be termed, is especially evident among the so-called scale insects (*coccidae*) and in the nearly related group of insects, the plant lice, (*aphididae.*) The methods of control that are successful with these insects are based upon this life habit of restricted motility and in the main consist of the use of what are known as "contact insecticides." These insecticides depend for their killing power, not upon the introduction of some toxic agent to the digestive tract of the insect, but upon the effect that the agency used may have upon the insect when in contact with it externally. They may be caustic in their action, actually destroying the tissues of the insect, and so bringing about its death, or they may be oily in their nature and depend for their killing power upon entering the body of the insect through the breathing pores. These are situated upon the sides of the body, and through them and their connecting tubes, (*tracheae*), air is carried to all parts of the insect's body. While the exact action of the oily sprays upon the insect's respiratory system is problematical, still the value of these sprays depends upon their effect on this system. A third class of contact insecticides depend for their value upon their tendency to loosen the insect from its situation upon the plant and permit the action of the weather upon the thus exposed pest to cause its death. Each of the methods above outlined has its value in particular cases and under certain conditions.

CONTROL OF SCALE INSECTS.

The two pests among the scale insects causing the greatest losses in this state are the so-called San Jose Scale (*Aspidiotus perniciosus* Comst.) and the New or West Indian Peach Scale (*Aulacaspis pentagona* Targ.) The San Jose Scale is well distributed throughout the whole state while the West Indian Peach Scale is not quite so widespread in its distribution. Both insects belong in the group known as the armored scales which means that the living creature is covered over with an armor like shell which is composed of the cast skins (*exuviae*) of the insect and of a waxy material secreted by it. In both cases the individuals are extremely small and it is only their great numbers that make them a dangerous pest. It is not our intention at the present time to enter into an extensive description of either of these insects. For a fuller discussion of the subject the reader is referred to Circular No. 1, issued from this department in October, 1906. It is enough to say here that the same means of control are applicable and recommended for both insects.

These consist solely of contact sprays and the one in most general use, and at present most satisfactory, is the so-called Lime-Sulfur-Salt spray. This may be made by the following formula:

Lime	30 pounds.
Sulfur	20 pounds.
Salt	5 pounds.
Water	60 gallons.

*Preparation.**—"For preparing the wash two vats or boilers are necessary, and if the spraying is to be done on a large scale, one of these, at least, should hold a couple of hundred gallons. If a smaller number of trees are to be treated, iron kettles will answer the purpose. Of course the preferable way of cooking the wash is by means of live steam.

Many ways have been suggested for mixing the materials, but the results are the same in every case, so long as the mixture has been subjected to the required amount of boiling. It is largely a matter of convenience, then, that determines the particular method, and the one found to best answer this requirement is as follows:

First, place two or three inches of water in the boiler, and to this add the sulfur, which has previously been made into a paste by mixing with hot water in order to remove the lumps, or sift the dry sulfur through a mosquito wire netting and stir in thoroughly. Then add about one fourth of the lime, and when the violent boiling has ceased add another fourth, and so on until the required amount of lime has been added. Hot water should be added with the lime as needed, so as to make the mixture a creamy consistency. Too much water will "drown" the lime while on the other hand too little, will cause incomplete slaking of the lime. In this way the heat generated by the slaking lime is taken advantage of, and by adding the sulfur first, plenty of time is given for removing the lumps.

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*From Alabama Agric. Exper. Station, Circular No. 1, Oct. 1906.

By the time the lime is thoroughly slaked the fire should continue the boiling, so that the time of boiling begins with the addition of the lime. The salt and about one-fourth of the water should now be added and the whole boiled from one to two hours, keeping it frequently stirred in the meantime. At the end of this period screen into the spray tank, add the necessary amount of *hot* water and apply to the trees hot.

The wash, when properly made, is a heavy reddish-brown liquid, very caustic and having a strong sulfur odor. The heavier materials settle upon standing, leaving a lighter liquid both in color and weight.

Application—On account of the heavier ingredients of the wash quickly settling to the bottom, means should be provided for agitating the mixture in the spray tank. This is best done, of course, by the power outfit. In the absence of this a gearing may be attached to the wheel of the wagon and the mixture agitated while going from one tree to another. A still simpler way is to stir frequently by means of a hoe or paddle.

The nozzle should be of the stopcock type, which will permit of ready cleaning. The type of spray should be a rather coarse one which will thoroughly wet the insects.

* * * * * * * * *

Thoroughness in application cannot be too strongly urged, and *no part of the tree should escape treatment.*

Time of application.—The Lime-Sulfur-Salt wash is for winter use only. It must not be used when trees are growing for very grave injury will be the result if it is applied at that time. When the trees are dormant it can be safely used upon them. Such weather conditions in the winter as will permit work in the orchard will be satisfactory for applying the Lime-Sulfur-Salt wash."

The difficulty attendant upon the preparation of this wash has led to a large amount of experimentation with other washes. Among the many materials used in this experimental work, the so-called "soluble oils" seem to offer the most promise and where winter work with the Lime-Sulfur-Salt preparation has been impossible, then it is advisable to use this material. It is known under different trade names and under the designation, "Scalecide," a quite desirable contact insecticide is sold. The spray made with this material can be used with safety in the spring and its results, when so used, are fairly satisfactory.

The main point to be observed in the use of this and all other contact insecticides is thoroughness of application. To be effective the material must come in direct contact with the insect to be destroyed.

PLANT LICE.

Another quite destructive series of insects with sucking mouth parts are the so-called "plant lice," the Aphids. These are soft bodied creatures, quite small, though generally larger than the scale insects, and are more easily destroyed than are the latter pests.

Certain species of aphids are well known to our truck gardeners, as for instance, the cabbage louse, (*Aphis brassicae*), while certain other series are quite destructive to orchard products and even to trees. When the attack of these insects is confined to the above ground parts of the tree or plant they can be quite readily destroyed by a spray made as follows: Dissolve one and one-half pounds of ordinary kitchen or laundry soap in one and one-half gallons of water. This can best be done by shaving the soap into boiling water and keeping the water boiling until the soap is fully dissolved. Remove from the fire and pour into the strong suds thus made one gallon of kerosene oil, stirring vigorously while pouring. Continue this vigorous stirring for fully ten minutes. The result should be a fairly stable creamy emulsion with no free oil. To the Kerosene Emulsion thus made add eighteen gallons of water and the spray is ready to be applied. It will be found quite effective as a destroyer of the majority of plant lice with which the grower will have to deal.

There are certain species of plant lice that attack not only the above ground portions but also feed upon the roots and root crowns of the trees. When our problem is the control of such insects as these, special methods of procedure are necessary. The best known of these pests is the Wooly Aphis of the apple—an insect that is familiar to all who are interested in the growth of this fruit. Very briefly we may say that the general method of procedure in such cases as these is to work in about the tree and root crown such materials as wood ashes or tobacco dust. These materials have a tendency to either destroy the insects or discourage their attack at the point where it is most damaging, the root crown. Special cases of this character, however, demand special study and treatment.

In the control of certain of the insects with sucking mouth parts no spraying or other method of ordinary procedure is of use and we are reduced to the practice of "hand picking" or jarring the insects off of the infested plants in our control efforts. This is true of the larger representatives of the series, as for example, the so-called "squash bug," (*Anasa tristis,*) where spraying is of little or no value and control is obtained only by the removal and destruction of the individual insects.

There are many other insects of the type with sucking mouth parts to which attention might be called but we believe the purpose of this paper is served in citing the instances above noted.

Whether the insect causing damage is of the biting or sucking type, a reasonable study of it and its activities allows us to apply remedial measures far more economically and with a greater hope of success than would be the case without this study. The purpose of this Bulletin will have been served if it brings about a closer study of the insect causes of loss in this state and a more intelligent application of remedial measures.

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STILLWATER, OKLAHOMA

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THE LOCUST BORER

BY C. E. SANBORN AND H. R. PAINTER

DEPARTMENT OF ENTOMOLOGY

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THE LOCUST BORER

(*Cyllene robiniae*, Forst.)

C. E. SANBORN
H. R. PAINTER

INTRODUCTION

The growing of first-class locust trees in this State is a difficult problem on account of the damage done by the locust borer. (See frontispiece.) This is one of the most injurious pests of the locust tree. The tree is well adapted to this country and is grown quite extensively, but unless insect damage is controlled to a greater degree in the future than in the past, there will be no profit in the growing of locust trees.

Locust trees may be extensively mined by the borers and yet not readily succumb. The injury, however, renders the trees unfit for posts. In Oklahoma many of these trees are grown for posts as well as for shade.

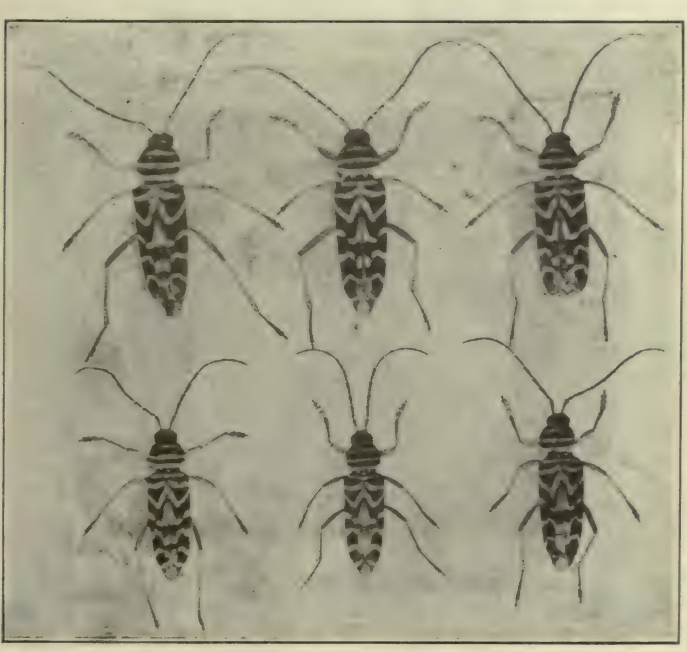

Figure 1—Adult locust borers; females above, males below; slightly enlarged

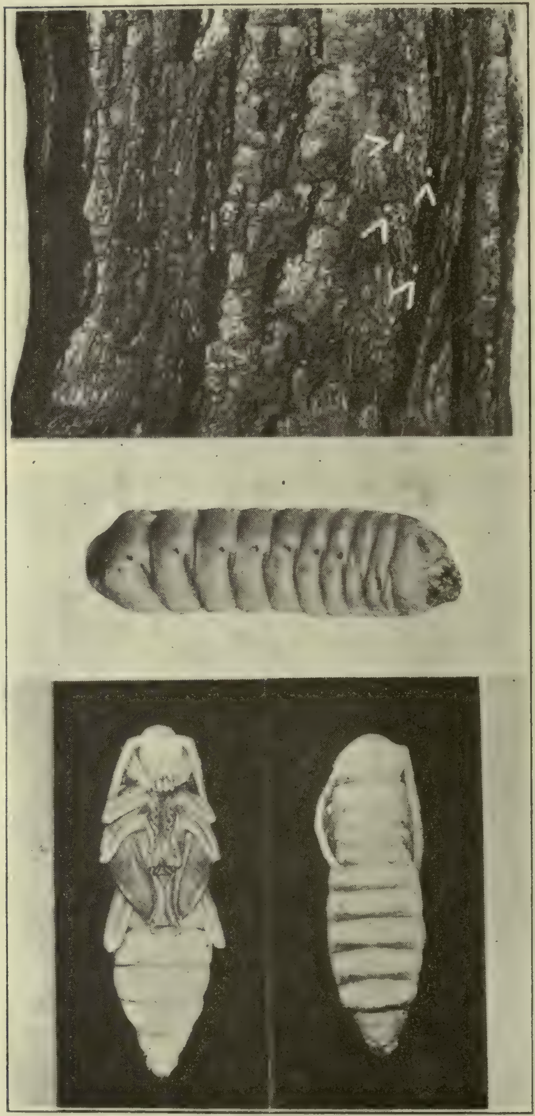

Figure 2—Above, section of bark showing eggs, natural size. At center, larva, slightly enlarged. Below, ventral view of pupa at left, dorsal view at right, twice natural size

DESCRIPTION OF BORER

Adult.—The beetle is about four-fifths of an inch in length and is blackish in color with yellow crossbars on the thorax and wing covers. The male is a little smaller than the female. The third crossbar on the elytra, or wing covers, is W-shaped. The elytra taper gently from the base to the rounded tips. Legs and antennae are reddish-brown.

This insect is quite similar to the hickory borer (Cyllene pictus), but is easily distinguished from it since this borer appears in the fall, while the hickory borer appears in the spring.

Egg.—The egg (shown in Figure 2) is about one-twelfth of an inch in length, somewhat tapering at one end and blunt at the other; color, white; surface, smooth.

Larva.—The larva (also shown in Figure 2), is a white, footless grub about one and one-fifth of an inch long when mature. Nine spiracles are present along the sides of the body. The one nearest the head is a little lower than the others. The head is small and dark colored.

Pupa.—Is seen in Figure 2, and is similar in color to the larva. The average length is nearly one inch. The appendages, except the wings and elytra (wing covers), are well formed but folded against the body. The wings are very feebly developed, while the wing covers are small, oblong pads about one-third of an inch long.

LIFE HISTORY

Adult.—The adult beetles appear about the middle of September. By means of screen wrapped around the trunks of a number of trees, and which were examined daily, it was possible to obtain accurate data regarding the date of appearance of the adults. Their food consists of pollen of flowers, chiefly that of the common goldenrod. The insects soon mate. The females then run about over the trunk and larger branches of the trees searching for places in which to deposit eggs. Mating may take place a number of times during the oviposition period. In one particular instance a pair was seen to copulate twice within three minutes. They remain in copula only a few seconds. The beetles are active during the warmer part of the day. Late in the afternoon they seek shelter in rubbish on the ground and remain there during the night.

Egg.—The eggs are generally placed singly in V-shaped crevices in the bark. (See Figure 2.) In some cases, however, a number of eggs may be placed in a group in an old wound. It requires only a few seconds for the deposition of an egg. The average number deposited by a single female has not been determined, but it is about one hundred. Eggs hatch about six or seven days after deposition.

Larva.—The young larva bores through the bark and remains active until cold weather. Then it ceases tunneling and lies in a dormant state throughout the winter.

During the fall the location of larvae can often be discovered by the presence of small, moist spots on the bark, as well as small masses of sawdust pushed out by the young borers through the openings of their tunnel. In the spring the larvae become active and burrow deeper into the tree, often penetrating the heartwood. From here the tunnels run upward from four to six inches. The larvae remain active throughout the summer, maturing about the middle of August.

Pupa.—Pupation takes place in the tunnel. This stage lasts from ten days to two weeks. About a day before the pupa transforms to the adult stage the yellow crossbars begin to appear on the thorax and wing covers. From specimens studied, it was learned that the insects do not always emerge from the trees immediately after transforming from pupae to adults, but remain for some time in the tunnels.

CONTROL

Disease.—Oftentimes dead larvae in various stages of development have been found in tunnels. It seems that this may have been due to disease, but thus far investigations do not warrant a definite conclusion.

Insect Parasites.—The wheelbug (Prionidus cristatus) is known to feed on the adults. It is not instrumental, however, in controlling an infestation of these beeltes. The enemy grasps the beetle and inserts its proboscis into the body of its host and feeds on the vital fluids.

Clean Cultivation.—Since the beetles feed mainly on the pollen of the goldenrod it would be well to destroy all such plants. By re-

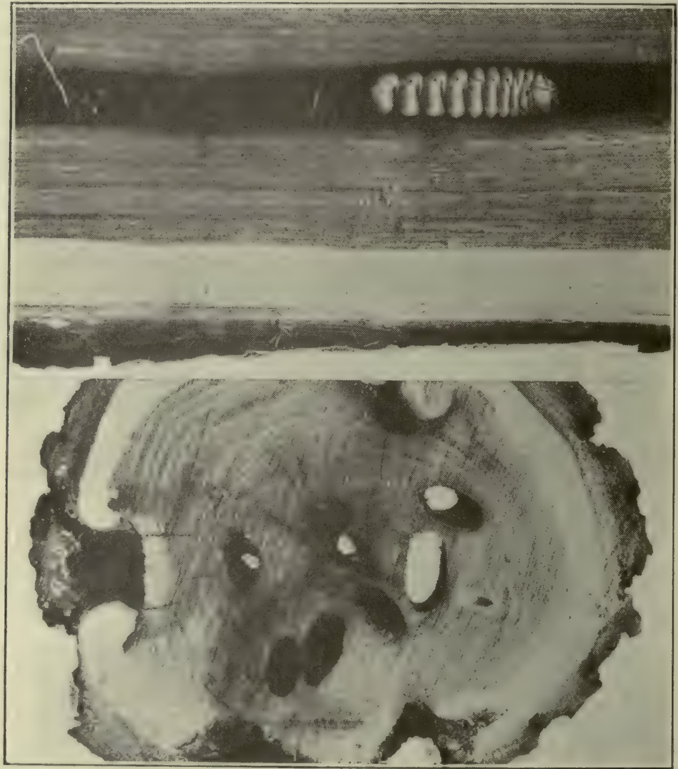

Figure 3—Above, Larva in tunnel; below, cross-section of tree trunk showing work of larvae; natural size

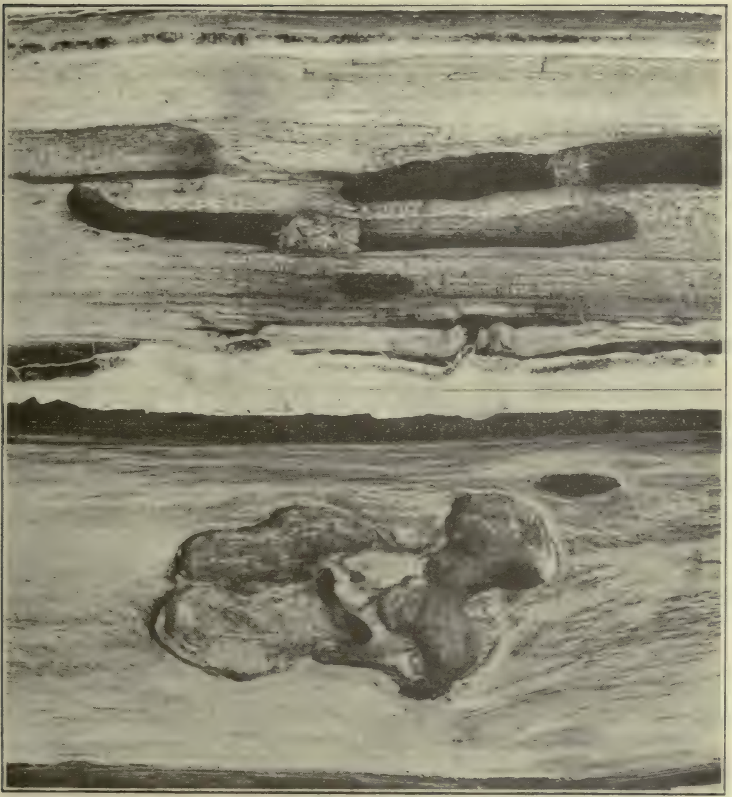

Figure 4—Above, tree trunk split open to show tunnels made by larvae. Natural size. Below, bark removed to show work of larvae; natural size

moving the food supply the development of eggs would be checked. Consequently the infestation would be reduced to a marked extent. The fact that the goldenrod is a very good honey plant makes this method somewhat objectionable in localities where bees are kept.

Whitewash.—A coating of whitewash applied to the trunk and main branches of the trees during late summer before oviposition begins will prevent much damage. The insects do not oviposit as readily in the bark coated with whitewash as they do on untreated bark. The application should be well made, that is, all cracks and crevices in the bark should be filled with the mixture.

Tanglefoot.—Bands of tanglefoot from two to five inches wide were applied to the trunks of trees about five feet above the ground to ascertain if this material might be effective in trapping the beetles. These bands remained in good condition during the entire fall, but not a single beetle was caught. Beetles placed in these bands by the experimenter were able to free themselvs from it. This shows that tanglfoot is ineffective so far as capturing the beetles is concerned.

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University of Maine

Maine Agricultural Experiment Station

ORONO

BULLETIN 259 FEBRUARY, 1917

PUPAE OF SOME MAINE SPECIES OF NOTODONTOIDEA.

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†In collaboration with U. S. Department of Agriculture.

BULLETIN 259

PUPAE OF SOME MAINE SPECIES OF NOTODONTOIDEA.*

EDNA MOSHER.†

INTRODUCTION.

It is only in recent years that entomologists have realized the value of studying the immature stages of insects, although immature forms are responsible for more damage to crops than adults. Now that the need for such studies is felt, it is surprising how very little we really know about the subject. The pupae have rarely been considered even from the standpoint of the systematist, much less from that of the economic entomologist. Nevertheless it is important to be able to recognize an insect pest at any stage of its life-cycle, even if it does no damage while in that stage.

These studies of the pupae of some of the commoner forms found in Maine will, it is hoped, lead to the easy recognition of the species described, and awaken an interest in this stage of the insect's life history.

The pupae were, for the most part, obtained by collecting the eggs or larvae and rearing them to maturity in order to identify the species, as will be necessary until the larval and pupal stages are more carefully studied. This work was done during the summer of 1915, but the season was not a favorable one for rearing Lepidoptera, being very cold and wet. Many of the specimens died of fungous or bacterial diseases, the Geometridae being especially hard to rear successfully. In some cases the life history has been supplemented by material from the author's private collection. The adults were identified partly by Dr. T. H. McDunnough of Decatur, Illinois, and partly by the author, while Dr. W. T. M. Forbes identified larvae of several species.

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*Papers from the Maine Agricultural Experiment Station; Entomology No. 90 and contribution from the Entomological Laboratories of the University of Illinois, No. 54.

†Member of the Station Summer Staff.

The synonymy used is, for the most part, that of Dyar's check list.

MORPHOLOGY.

The pupae described here belong to the type known as obtected pupae because all of the appendages are firmly soldered to the body wall and have no power of independent movement. In order to understand the following descriptions, the terms used will be briefly described.

A hypothetical pupa is shown in Fig. 2, A and B to which reference will be made under the discussion of the different structures.

THE HEAD

Vertex. The vertex is found on the dorsal surface of the head. In the pupae described here, it is confined to a small, triangular area adjacent to each antenna (Fig. 2, B, v). The vertex is bounded cephalad by the epicranial suture (Fig. 2, B, es), but only a portion of each of the epicranial arms is visible.

Front. The front (Fig. 2, A, f) is the sclerite to which the antennae are attached. It is separated from the vertex, when this is present, by the epicranial suture. The fronto-clypeal suture is not present, but the front includes most of the ventral surface of the head.

Clypeus. This sclerite (Fig. 2, A, cl) cannot be definitely bounded in specialized pupae. The invaginations for the anterior arms of the tentorium (Fig. 2, A, at) which are always distinct, are located along its lateral margin.

Labrum. The labrum (Fig. 2, A, lb) is caudad of the clypeus and is not separated from the clypeus by a suture. Its other margins are always distinct.

Eye-pieces. These are situated mesad of the antennae and each is composed of two parts, a narrow smooth portion along the mesal margin called the glazed eye-piece (Fig. 2, A, ge) and a broader lateral portion called the sculptured eye-piece (Fig. 2, A, se). These are often hard to distinguish in smooth pupae.

Antennae. These are easily located (Fig. 2, A, a) being attached to the front and curving laterad along the margin of the head, extending on to the ventral surface of the thorax and abdomen along the edge of the mesothoracic wing.

Labial Palpi. Only a very small portion of the labial palpi is visible just caudad of the labrum (Fig. 2, A, lp).

Maxillae. The maxillae (Fig. 2, A, mx) lie adjacent on the meson and vary greatly in length. They are measured on the meson from the caudal margin of the labrum to their distal end, (Fig. 2, A, a). This length is compared with the distance on the meson from the caudal margin of the labrum to the caudal margin of the wings (Fig. 2, A, ac).

The parts of the head, exclusive of the appendages, are referred to as the face-parts.

THE THORAX.

Prothorax. This segment (Fig. 2, B, p) is normally about one-third the length of the mesothorax.

Prothoracic Legs. These lie adjacent to the maxillae (Fig. 2, A, 11). The legs are folded so that normally only the surface of the tibia and tarsus are exposed. In generalized forms, however, a portion of the femur is visible (Fig. 2, A, f1). These legs are about half the length of the wings in the great majority of pupae.

Mesothorax. The mesothorax (Fig. 2, B, ms) is the longest segment of the body, and is normally from two to three times the average length of the abdominal segments.

Mesothoracic Spiracle. The opening to this spiracle referred to in the text as the mesothoracic spiracle (Fig. 2, B, msp), is found at the cephalo-lateral angle of the mesothorax, between that segment and the prothorax. The real spiracle is down below the surface in the conjunctiva between the two segments.

Mesothoracic Legs. These are folded just like the prothoracic legs and lie adjacent to them, but their femora are never exposed (Fig. 2, A, 12). The part referred to as mesothoracic leg is in reality the outer surface of the tibia and tarsus. These legs are from three-fifths to three-fourths the length of the wings in the majority of pupae.

Mesothoracic Wings. The wings of the mesothorax (Fig. 2, A, w1) almost conceal those of the metathorax and are visible on both dorsal and ventral surfaces. In most pupae they are the only wings visible on the ventral surface.

Metathorax. This segment (Fig. 2, B, mt) is usually about as long as the first abdominal segment.

Metathoracic Legs. These legs (Fig. 2, A, 13) are never visible for their entire length, and are sometimes entirely concealed. The tips are often visible on either side of the meson near the caudal margin of the wings.

Metathoracic Wings. These are usually concealed by the mesothoracic wings except for a narrow strip along the dorsal margin (Fig. 2, A, w2). In Platypterygidae they are visible on the ventral surface.

ABDOMEN.

The abdomen consists of ten segments (Fig. 2, B, a1 to a10). The first three segments are only visible in dorsal view. The fourth usually shows a slight margin below the wings on the ventral surface and all of the other segments are visible on both surfaces. There is movement possible between the fourth and fifth, fifth and sixth, and sixth and seventh segments, and the fourth, fifth and sixth are said to be movable segments. The pupa is thus capable of expanding and contracting the body and can bend it from side to side. The movements possible between these segments enables the pupa to work its way out of the ground, or out of a cocoon. These movable segments generally fit over one another so that the transverse conjunctiva of one covers the cephalic portion of the next segment. This cephalic portion is referred to as the cephalic margin (Fig. 2, B, cm). The transverse conjunctiva differs from the remainder of the segment in texture and is usually lighter in color. Its cephalic boundary is indicated in the figures by a dotted line.

Tubercle Scars. The larvae often bear prominent tubercles or projections on the body and the scars (Fig. 2, B, ts) of these are nearly always visible on the body of the pupa.

Anal Opening. This is situated on the meson near the caudal margin of the tenth segment (Fig. 2, A, ao). It is usually slit-like and surrounded by prominent wrinkles or folds.

Genital Openings. The sexes may be easily distinguished by the position of the genital opening (Fig. 2, A, go). That of the male is situated on the meson of the ninth segment. That of the female is situated mostly on the eighth segment or on both eighth and ninth segments. The cephalic margins of segments eight and nine curve strongly cephalad in the female, and this alone is sufficient to indicate the sex. In generalized pupae there are two unpaired genital openings in the female, a condition retained by many of the specialized forms.

Abdominal Spiracles. These (Fig. 2, B, s) are present on the first eight segments but are never visible on the first segment, being entirely covered by the wings. The spiracle on the eighth segment is never functional and shows no distinct opening.

Spiracular Furrows. These are found on the cephalic margin of some or all of the movable segments just cephalad of the spiracles (Fig. 2, B, sf). In many genera they are only present on the fifth segment. In some genera there are a number of low ridges, in others a very distinct pocket-like invagination.

Cremaster. The cremaster (Fig. 2, B, cr) is a prolongation of the tenth segment. It is of various shapes and lengths and often separated from the tenth segment by a depression. Its length is measured on the ventral surface, from its junction with the curve of the tenth segment to the distal end. In Fig. 2, A, ab represents the cremastral length.

CLASSIFICATION.

The superfamily Notodontoidea, as considered in this paper, includes the families Geometridae, Notodontidae and Platypterygidae. The family Dioptidae also belongs to this superfamily but there are no species in the eastern states.

The pupae of this superfamily are not always easy to separate from those most closely related, the Noctuoidea and Bombycoidea. As in the case of the larvae and adults, there is no one prominent character by which they may be recognized, and it is only a careful comparison of several characters that enables us to recognize the pupae of the Notodontoidea. The labial palpi are seldom exposed, and then only a small triangular or polygonal portion caudad of the labrum, thus differing from the great majority of the families Noctuidae, Liparidae, and Lasiocampidae in which they are often visible for one-fifth the length of the wings. There are no prominent setae on the body, which separates them from most of the Arctiidae, Liparidae, Lasiocampidae, and some Noctuidae. As a general rule only the prothoracic leg extends cephalad between the sculptured eye-piece and the antenna. Nearly all of the Noctuidae which do not show a large portion of the labial palpi and prothoracic femora, have both prothoracic and mesothoracic legs extending cephalad between the sculptured eye-piece and the antenna.

Briefly summarized the characters of the superfamily Notodontoidea are as follows: Epicranial suture very seldom visible; antennae separated from the face-parts by a distinct suture, always broadest at the proximal end, the greatest width about equal to that of the prothoracic legs, but never much broader; labial palpi seldom visible, and then only a small triangular or polygonal portion caudad of the labrum; prothoracic femora only exposed in the generalized families of Geometridae; mesothoracic leg very seldom extending cephalad between the sculptured eye-piece and the antenna; body surface never densely covered with setae or having prominent setae arranged in rings or around prominent oval areas; abdominal segments usually punctate; cremaster usually present, and setae at the distal end always hooked.

The dorsal surface of the abdomen frequently shows a deep furrow between the eighth and ninth abdominal segments. The caudal margin of this furrow is usually serrate or crenulate. There are also spiracular furrows found in many species. These vary in number and form, and are mostly found in the Geometridae. The families of Notodontoidea may be separated as follows:

a. Metathoracic wings never visible on the ventral surface of the body.
  b. Maxillae usually more than three-fifths the length of the wings, if not, then the caudal end of the body with hooked setae, or the spiracles of the third abdominal segment concealed by the wings and those of the sixth segment farther ventrad than those of the other segments; prothoracic femora sometimes exposed; a deep

furrow usually present on the dorsum of the abdomen between the ninth and tenth segments; caudal margin of mesonotum never with a row of deep pits with smooth tubercle-like areas between. *Geometridae.*

bb. Maxillae seldom exceeding three-fifths the length of the wings, if so, then the caudal margin of the mesothorax with a row of deep pits with smooth, elevated. quadrangular, tubercle-like areas between them, or with the entire body surface coarsely punctate; abdominal spiracles of the third segment never concealed by the wings, and those of the sixth never farther ventrad than the remainder; prothoracic femora never exposed; a furrow never present on the dorsum of the abdomen between the ninth and tenth segments except in Datana where the cremaster is of the type shown in Fig. 5, E to H. *Notodontidae*

aa. Metathoracic wings meeting on the meson caudad of the mesothoracic legs, and visible along the caudal margin of the mesothoracic wings. *Platypterygidae.*

Family GEOMETRIDAE.

The pupae of this family are, with a few exceptions, less than an inch in length. The majority of species are about half an inch long. They are either found suspended from leaves with the cremaster fastened in a mat of silk, much as the chrysalids of butterflies, or they may be found in thin cocoons attached to a leaf, or in a cell in the ground. The legs are longer than is usual in lepidopterous pupae, the prothoracic legs usually three-fourths the length of the wings; the mesothoracic legs normally reaching the caudal margin of the wings, or only separated by a very short distance. This is the best single character to separate the pupae of Geometridae from those of the other families. The epicranial suture is present in a very few genera. The labial palpi are sometimes exposed as small triangular or polygonal areas caudad of the labrum. The prothoracic leg and occasionally the mesothoracic also, extends cephalad between the sculptured eye-piece and the antenna. The femur of the prothoracic leg is sometimes exposed, often only a very narrow portion, which might easily be overlooked. The maxillae are always long, nearly always extending to the caudal margin of the wings. The antennae vary little throughout the family. They are usually about as wide as the prothoracic legs, measuring the proximal part of both, and are gradually narrowed to the distal end, which usually extends to the caudal margin of the wings. The metathoracic wings usually extend along the margin of the mesothoracic wings on the dorsal surface, but are not visible in ventral view. The mesothorax is very short in some genera and the entire thorax sometimes very short in relation to the remainder of the body. The mesothoracic spiracles often have a decided projection adjacent to their caudal margin. This may be a sharp ridge, or it may be a prominent tubercle which is often flattened and bears numerous short setae. The abdominal spiracles are sometimes produced and very often the spiracles on the sixth segment are considerably ventrad of the others. Spiracular furrows are frequently present, varying greatly in size and number. The dorsal furrow between the ninth and tenth abdominal segments is present in many genera. It often bends caudad near the lateral margin of the body and this lateral extension may reach to the base of the cremaster. A cremaster of some type is always present. In the pupae examined during this investigation only two types were found, the triangular type with hooked setae, and the bifurcate type, with or without hooked setae.

The coloring of the pupa varies considerably in this family. While the majority are chestnut or darker brown, in common with most lepidopterous pupae, there are some which are nearly white, others yellowish, and various shades of yellowish and reddish brown. Some are conspicuously marked with black or dark brown and one of the pupae described has a beautiful pearly luster. The genera described here may be separated as follows:

a. Cremaster with prominent hooked setae at the distal end, but never bifurcate.
  b. Cephalic end of body very blunt and each cephalo-lateral angle prominently produced; a large portion of the prothoracic femur exposed. *Cosymbia.*
  bb. Cephalic end of body rounded; the prothoracic femur never visible, or only a very narrow portion of it exposed.

- c. Dorsal furrow never present between the ninth and tenth abdominal segments; antennae usually reaching the cephalic margin of the fifth abdominal segment. *Aplodes.*
- cc. Dorsal furrow always present between the ninth and tenth abdominal segments; antennae seldom extending beyond the caudal margin of the wings.
  - d. Caudal margin of the dorsal furrow between the ninth and tenth abdominal segments with very small, inconspicuous projections; the two lateral setae adjacent to the mesal setae or spines on the cremaster larger than the others. *Ania.*
  - dd. Caudal margin of the dorsal furrow between the ninth and tenth abdominal segments with prominent projections; lateral setae of the cremaster all of the same size.
    - e. Abdomen never densely punctate, either smooth or with shallow impressed lines; color never brown.
      - f. Body white, conspicuously marked with black, never iridescent. *Cingilia.*
      - ff. Body pale yellow or green, always iridescent. *Sicya.*
    - ee. Abdomen densely punctate; color always brown.
      - f. A small portion of the prothoracic femur exposed; head never showing three small tubercles at the cephalic end. *Sabulodes.*
      - ff. Prothoracic femur never exposed; head always showing three small tubercles at the cephalic end. *Abbotana.*

aa. Cremaster always bifurcate at the distal end, often with hooked setae, but these weak and easily broken.

- b. Prothoracic femur exposed.
  - c. Dorsal furrow never present between the ninth and tenth abdominal segments, nor a prominent dorsal furrow on the fifth abdominal segment.
    - d. Cephalic margin of fifth abdominal segment with a furrow over each spiracle; mesothoracic spiracle never with a prominent ridge adjacent to its caudal margin. *Cleora.*

dd. Cephalic margin of fifth abdominal segment with four or five shallow furrows over each spiracle: mesothoracic spiracle always with a prominent elevation adjacent to its caudal margin. *Diastictis.*

cc. Dorsal furrow present between the ninth and tenth abdominal segments, and a very prominent one on the dorsum of the fifth abdominal segment. *Hydria.*

bb. Prothoracic femur never exposed.

c. Dorsal furrow never present between the ninth and tenth abdominal segments; a prominent tubercle never present adjacent to each mesothoracic spiracle. *Paleacrita.*

cc. Dorsal furrow always present between the ninth and tenth abdominal segments; a prominent tubercle adjacent to each mesothoracic spiracle. *Erannis.*

Genus COSYMBIA Hübner.

Body much wider at the cephalic end and truncate, the cephalo-lateral angles distinctly produced; face-parts considerably elevated, a transverse ridge extending across the front on a line with the cephalic angle of the eye-pieces; labrum quadrate in outline; labial palpi not visible; maxillae reaching nearly to the caudal margin of the wings, the proximo-lateral angles not quite reaching the eye-pieces; prothoracic legs almost three-fourths the length of the wings, their femora exposed; the legs reaching cephalad between the sculptured eye-pieces and the antennae; mesothoracic legs reaching the caudal margin of the wings, always longer than the maxillae; tips of the metathoracic legs showing caudad of the maxillae; prothorax on the blunt cephalic end of the body, scarcely visible in ventral view, its mesal length one-third that of the mesothorax; mesothoracic spiracle with a large rounded tubercle adjacent to its caudal margin which form the produced cephalo-lateral angles of the body as seen in either dorsal or ventral view; mesothorax with a distinct lateral ridge which extends from the base of the spiracular tubercle caudad to near the anal angle of the wing; mesal length of metathorax one-fourth that of the mesothorax, the caudal margin curved slightly at the meson; abdominal segments smooth, never punctate; abdominal spiracles small, elliptical, those of the second segment covered by the wings; no spiracular furrows present; no dorsal furrow present between the ninth and tenth abdominal segments but a very distinct constriction or furrow at the base of the cremaster; cremaster triangular, longer than broad, the distal end with six strong hooked setae and two finer hooked setae just cephalad of these.

COSYMBIA LUMENARIA Hübner.

Fig. 2, C.

Color usually bright green with three interrupted, longitudinal white stripes on the dorsum, one of these on the meson and one on either side, a broader, less interrupted white stripe through the spiracles, the body more or less mottled between the stripes with either small black or white blotches; lateral ridge usually with a narrow white stripe on the dorsal side and a broader black stripe on the ventral; body often entirely white with the black stripe near the lateral ridge; head, thorax, and appendages smooth, or with very fine transverse striations, antennae at proximal end equal to greatest width of the prothoracic legs, but narrowing rapidly so that they are only one-third as wide at the distal end; abdomen smooth, the segments tapering gradually to the caudal end of the body.

Length 10 to 11 mm.; greatest width 2.5 to 3 mm.

The larvae were very abundant on sweet fern and were often found feeding along the edge of the leaf. Some of the larvae were about an inch long, pale green, with white dorsal stripes much as described for the pupae, with fine powdery white dots between, others were brown with indistinct white stripes and darker brown oblique lines or blotches, and seemed to be entirely different, while the pupae and the adults would be exactly alike, or at least appeared to be. Larvae were abundant all through July, and many pupae were collected the latter part of the month and in August. The larvae spin a little knot of silk and fasten themselves to it and then transform to pupae. They are suspended like many butterflies with the hooks of the cremaster fastened into the web of silk and a fine white silken thread around the middle of the body. There is never any trace of a cocoon. The moths emerged in August and many were seen flying about, but the egg-laying habits were not observed.

Genus APLODES Guenée.

Body of usual shape, blunt at the cephalic end, entire body surface roughened with deep, indeterminate, impressed lines; a small portion of the labial palpi exposed caudad of the labrum; antennae extending beyond the caudal margin of the wings, reaching the caudal margin of the transverse conjunctiva when the body is expanded, each distal end curved slightly towards the meson; maxillae never quite reaching the caudal margin of the wings, the tips of the metathoracic legs exposed just caudad of them and between the distal ends of the antennae; proximolateral angles of the maxillae not extending to the eye-pieces; prothoracic leg extending cephalad between the sculptured eye-piece and the antenna, about three-fourths the length of the wings, the femur never exposed; mesothoracic legs reaching the caudal margin of the wings and slightly longer than the maxillae; mesal length of prothorax two-thirds that of the mesothorax; opening of the mesothoracic spiracle on a slightly elevated tubercle; mesal length of the metathorax one-fourth that of the mesothorax; metathoracic wings showing a large triangular piece adjacent to the second and third abdominal segments and almost forming a right angle opposite the third abdominal segment; abdominal spiracles almost circular in outline; a dorsal furrow never present between the ninth and tenth abdominal segments; sutures between all of the abdominal segments very distinct; cremaster broadly triangular, continuing the outline of the body except for a slight constriction at its proximal end, armed with eight hooked setae, of which the two mesal ones are slightly longer.

APLODES MIMOSARIA Guenée

Fig. 3, E.

Body variously colored, usually grayish green, sometimes yellowish brown, often tinged with reddish or orange shades, always with a darker dorso-mesal stripe, and dotted with black or dark brown, the bases of the setae conspicuously dark brown or black; cephalic end of body showing a small tubercle on the meson just caudad of the proximal ends of the antennae; proximal ends of the antennae slightly elevated and somewhat tuberculate, especially along the middle line; wings slightly elevated along the dorso-lateral margin; abdominal spiracles almost circular in outline, usually slightly elevated, the spiracle of the sixth abdominal segment considerably ventrad of the others; abdominal segments roughened with indeterminate transverse impressions and sparsely punctate; cremaster less than 1 mm. in length, the two caudal setae of each side curved cephalad, the remainder curved caudad.

Average length 12 mm.; greatest width 3 mm.

The larvae of this species were very abundant on sweet fern. They differ from the majority of geometrid larvae in having the lateral margins of most of the abdominal segments produced into triangular projections one on each side of a segment, which makes the lateral margin of the body very strongly toothed. These projections often curve slightly dorsad. The larvae were about an inch long and variously colored. Some were all green, others were tinted with yellowish and reddish colors like autumn leaves, while others were pale yellow tinged with red. The pupae were less variable in color, and no difference could be detected in the adults. The larvae were very difficult to locate as they fed along the edge of the sweet fern leaves, and the notches on their body corresponded in a general way to the notches in the leaves. Many of them were taken by sweeping. The first larvae were collected July 23 and they were abundant till the middle of August. By the third week in August practically all had pupated. The larvae spin a few threads of silk between two leaves and the pupa is held in place in the entanglement of the silk by the hooks on the cremaster.

Genus ANIA Stephens.

Body widest near the cephalic end; surface roughened with deep indeterminate impressed lines on head, thorax and appendages, densely punctate on the abdomen, never presenting a polished appearance; face-parts elevated, the head with a rounded, transverse ridge just caudad of the proximal ends of the antennae; a small portion of the labial palpi exposed caudad of the labrum; maxillae about seven-eighths the length of the wings, the proximo-lateral angles never reaching to the eye-pieces; prothoracic legs about three-fourths the length of the wings, their femora never exposed; mesothoracic legs longer than the maxillae and meeting on the meson caudad of them, often separating to show a small portion of the tips of the metathoracic legs; both prothoracic and mesothoracic legs extending cephalad between the sculptured eye-pieces and the antennae; antennae reaching to the caudal margin of the wings and meeting on the meson; prothorax about half the length of the mesothorax; mesothoracic spiracles with the caudal margin elevated and somewhat flaring; abdominal segments 1 to 8 densely punctate; abdominal spiracles elliptical, slightly produced; spiracular furrows present on segments 5 to 7, the surface of the furrows punctate like the remainder of the segment; furrow present on the dorsum between the ninth and tenth abdominal segments, the edges very finely serrate; cremaster triangular in outline, rugose, with two large long hooked spines at the distal end, at the base of these two stout hooked setae, and cephalad of these two hooked setae near each lateral margin, forming a transverse row.

This genus consists of a single species in North America.

ANIA LIMBATA Haworth.

The Horned Span-worm. Fig. 2, E and H.

General color light brown, with darker brown markings, most of these small, irregular spots; antennae with dark brown inverted V-shaped markings; ventral surface of abdomen showing three broad stripes, the mesal one more distinct than those near the lateral margin; dorsal surface of abdomen with broad, indistinct, oblique bands of a lighter color; bases of the setae dark brown, and usually the distal portion of the cremaster; antennae slightly elevated, with a row of minute tubercles along the middle line; abdominal segments 1 to 8 finely, densely punctate, the ninth and tenth segments smooth; segments two and three with a more or less distinct tubercle on each side the meson indicating the scars of the larval filaments; segments five, six and seven with a distinct elevation along the cephalic margin; dorsal furrow between segments nine and ten with a lateral extension, the caudal margin (Fig. 2, H) notched on the meson and slightly serrate; cremaster 1 mm. long, slightly rugose, and showing a slight constriction on each lateral margin at the base.

Average length 9 mm.; greatest breadth 3 mm.

The larvae of this species are easily recognized by the group of four filaments that stand up on the back with their ends slightly curled. The first pair is attached to the second abdominal segment. They feed on various plants and were collected at Orono on sweet fern during the first week in August. The larvae pupated the fifth of August between the leaves of sweet fern, but did not form a cocoon.

Genus CINGILIA Walker.

Body slender, but of usual type; labrum quadrangular; a small polygonal portion of labial palpi exposed caudad of the labrum; antennae extending to the caudal margin of the wings, their greatest width greater than that of the prothoracic legs, their distal ends usually meeting on the meson; maxillae almost reaching the caudal margin of the wings, the proximo-lateral angles not extending laterad to the eye-pieces; prothoracic legs three-fourths the length of the wings, their femora never exposed; mesothoracic legs seven-eighths the length of the wings; only the prothoracic leg extending cephalad between the sculptured eye-piece and the antenna; mesal length of prothorax two-fifths that of the mesothorax; metathorax about half the length of the prothorax and slightly shorter than the first abdominal segment; abdominal segments with shallow, transverse impressed lines; dorsal furrow between the ninth and tenth abdominal segments present, the caudal margin crenulate; cremaster without a furrow at the base, ending in two long hooked spines with one short hooked seta on each side, a transverse row of four similar setae just cephalad of these.

This genus includes a single species in America.

CINGILIA CATENARIA Drury.

The Chain-dotted Geometer. Fig. 4, C and F.

Color white with conspicuous black blotches, the largest of these on the dorsum of the first five abdominal segments, the wing veins and some of the sutures lined with black; entire surface of body with shallow transverse impressed lines; antennae elevated, highest along the middle line, transversely lined with black; mesothoracic spiracles split-like; abdominal spiracles without any outer margin, the openings elliptical; cremaster (Fig. 4, F) with two large spines and six smaller ones.

Length 15 to 18 mm.; greatest width 3.5 to 4 mm.

The larvae of this species are pale yellow with some narrow dark brown or black stripes and marked with conspicuous black spots near the spiracles and on the lower part of the body. They feed on numerous plants, and specimens were collected from larch and sweet fern August 8. They pupated shortly after, spinning a very loose open cocoon through which the pupa could be easily seen. The cocoon was attached either to a leaf or a stem. The adults are white, and also conspicuously marked with black. They emerge in September.

Genus SICYA Guenée.

Body of usual type; surface smooth with a few punctures on the abdomen; labial palpi represented by a small triangular area caudad of the labrum; maxillae seven-eighths the length of the wings, the proximo-lateral angles scarcely reaching to the eye-pieces; antennae elevated, extending to the caudal margin of the wings, their greatest width slightly greater than that of the prothoracic legs, and meeting or approaching each other on the meson; prothoracic legs about two-thirds the length of the wings, extending cephalad between the sculptured eye-pieces and the antennae; mesothoracic legs nearly as long as the wings, meeting on the meson just caudad of the maxillae; mesal length of prothorax about half that of the mesothorax, while the metathorax is one-fifth of this length; mesothoracic spiracle slit-like, the cephalic margin slightly elevated; spiracular furrows not present; dorsal furrow present between the ninth and tenth abdominal segments, the caudal margin showing two large projections; cremaster triangular, longer than the tenth segment, two large hooked spines or setae at the end, with three smaller, but heavy hooked setae on each side just cephalad of the others.

SICYA MACULARIA Haworth.

Fig. 2, D and G.

Color pale yellow and green with silvery and pale green iridescence; surface smooth and polished, the setae rather conspicuous under the microscope and arising from small brown tubercles; median line of thorax brown, also a line indicating the suture at the base of each antenna, the spiracles, the glazed eye-piece, the margin of the prothorax, and the cremastral hooks; abdominal segments 1 to 7 with a few, very fine punctures which are scarcely apparent, segments 3 and 4 have a row of larger punctures along the cephalic margin of the segment, while segments 5 to 7 have a few larger ones scattered over the surface of the cephalic margin; abdominal spiracles almost circular, produced, the openings ovate in outline; cremaster (Fig. 2. G) with a distinct furrow at base, the dorsal surface depressed below the level of the tenth segment, and rugose with fine longitudinal striations; cremaster 1 mm. in length, the lateral hooks flattened and broader at the end.

Length 12 mm.; greatest width 4 mm.

The larva of this species was ready to pupate when collected, and therefore no description was obtained. It was collected July 2 on wild white spiraea. The larva first spun a very open web of silk which bent over the tip of the leaf and fastened it down. This web was drawn around the larva to form a sort of cocoon. The pupa at first was pale green with a brown median line on the thorax and brown around the spiracles. The dorsum of the body was lighter in color than the remainder, and had the appearance of being powdered. The body showed a beautiful iridescence even then, but in three days more it was fully hardened, a sort of yellowish-green in color and iridescent over the entire surface. The adult emerged July 16.

Genus SABULODES Guenée.

Body of usual type; surface always dull in appearance, considerably roughened with deep indeterminate transverse, impressed lines on head, thorax, and appendages, the abdomen densely punctate; labial palpi represented by a small polygonal area caudad of the labrum; proximo-lateral angles of maxillae never reaching the eye-pieces; maxillae, antennae and mesothoracic legs normally reaching the caudal margin of the wings, sometimes falling a little short of it; prothoracic leg about two-thirds the length of the wings, a very narrow portion of the femur exposed; the prothoracic legs extending cephalad between the sculptured eye-pieces and the antennae; the mesothoracic leg scarcely reaching the level of the glazed eye-piece in some species and extending farther cephalad in others; mesal length of prothorax one-half that of the mesothorax; metathorax one-fifth the length of the mesothorax and shorter than the first abdominal segment; mesothoracic spiracle slit-like; abdominal segments 1 to 8 punctate; furrow present on the dorsum between the ninth and tenth abdominal segments, the caudal margin coarsely toothed, the lateral extensions reaching almost to the base of the cremaster; cremaster longer than the tenth segment, bearing two stout curved spines at the distal end, with slender hooked setae along each lateral margin, the ventral surface with two deep parallel furrows, one near each lateral margin.

The species of Sabulodes may be separated as follows:

a. Face-parts with a prominent transverse ridge between the eye-pieces; body setae arising from small papillae; caudal margin of furrow between the ninth and tenth abdominal segments with small projections or teeth. *transversata.*

aa. Face-parts never with a prominent transverse ridge between the eye-pieces; body setae arising from small depressions; caudal margin of the furrow between the ninth and tenth abdominal segments with large projections. *lorata.*

SABULODES LORATA Grote.

Fig. 4, B and E.

Color yellowish brown, the spiracles, tenth segment, and cremaster always darker brown, an irregular dark spot on each side the dorso-meson of the first eight abdominal segments and one on the mesothorax at about the middle of its length, also fine irregular blotches on other parts of the body which are exceedingly variable; antennae more elevated than the other appendages, highest along the middle line, the surface covered with small tubercles; abdominal segments 1 to 8 densely punctate with medium punctures, the ninth and tenth segments smooth; body setae arising from small pits; abdominal spiracles with the openings elliptical; spiracular furrows never present; dorsal furrow between the ninth and tenth segments edged with black or very dark brown, with four prominent teeth on each side the meson; cremaster (Fig. 4, E) 1.5 mm. in length, the dorsal surface with deep longitudinal furrows and a transverse furrow at the base, a hooked seta laterad at the base of each large curved spine and a transverse row of four hooked setae of the same size at about one-third the length of the cremaster from the distal end.

Average length 18 mm.; greatest width 4.5 mm.

The larvae of this species are slim brown loopers with three rather prominent tubercles and a ridge on the dorsum of the body. They were only taken from sweet fern. When full grown they attach themselves to the leaves with a few threads of silk and usually pull another leaf over it, so that the pupa is entirely concealed.

SABULODES TRANSVERSATA Drury.

The Large Maple Span-worm. Fig. 4, K.

Color usually yellowish brown, the head, thorax, and appendages of many individuals a much darker brown; the cremaster usually dark brown; surface of body roughened with impressed lines and striations and somewhat tuberculate, there being small distinct, whitish tubercles visible on the appendages and on the eye-pieces; face-parts with a distinct, high, rounded transverse ridge extending from just cephalad of the middle of each glazed eye-piece; antennae tuberculate, the proximal fifth elevated along the middle line and forming a ridge; setae of thorax and abdomen arising from small, dark brown papillae; abdominal segments with the punctures mostly obscured by the ridges, except on the seventh and eighth segments, the ninth and tenth segments smooth; abdominal spiracles usually edged with darker brown, those of the second, third and fourth segments touching the wings, the lips of the openings slightly produced and somewhat crescent-shaped; spiracular furrows indicated on the fifth segment; dorsal furrow between the ninth and tenth abdominal segments distinct, the caudal margin edged with black and finely toothed; cremaster with four longitudinal ridges and a transverse furrow at base, four of the hooked setae inserted on the dorsal surface, and two on the lateral margin.

Average length 17 mm.; greatest width 5 mm.

The larvae of this species were collected from maple, but they are found on other kinds of trees. They are two inches or more in length, dark grayish brown and the mesothorax somewhat swollen at the sides. They pupate by attaching themselves to the leaves with a few threads of silk and then folding the leaf over, or attaching another leaf to it with the silk. These threads of silk do not form a cocoon. The pupa fastens itself to the silk by means of the cremastral hooks. The larvae are found in July and pupate early in August.

Genus ABBOTANA Hulst.

Body of usual type; surface always dull in appearance with deep impressed lines on the head, thorax, and appendages, and densely punctate on the abdomen; cephalic end of body showing three small tubercles between the antennae; labial palpi represented by a small polygonal area caudad of the labrum, proximolateral angles of the maxillae never reaching the eye-pieces; maxillae and antennae reaching the caudal margin of the wings; prothoracic legs two-thirds the length of the wings, the femora never exposed; mesothoracic legs a little shorter than the maxillae and never reaching the caudal margin of the wings; both prothoracic and mesothoracic legs extending cephalad between the sculptured eye-piece and the antenna; mesal length of prothorax one-half that of the mesothorax; that of the metathorax shorter than the first abdominal segment; mesothoracic spiracles slit-like, showing a narrow very slightly elevated ridge along the caudal margin; abdominal segments 1 to 8 punctate, the tenth segment irregularly rugose; furrow on the dorsum between the ninth and tenth segments distinct, the caudal margin coarsely toothed, the lateral extensions never reaching to the base of the cremaster; cremaster longer than the tenth segment, bearing two very stout spines at the distal end and slender hooked setae along each lateral margin, the ventral surface with a deep furrow on each side.

This genus includes a single species *Abbotana clemataria* found throughout the eastern part of the United States.

ABBOTANA CLEMATARIA Smith and Abbot.

Color chestnut brown, variously mottled with very dark brown or black, the darker color always conspicuous around the spiracles and on the cremaster; head, as seen in ventral view, with three small tubercles along the cephalic margin, one on the meson, and one on each side of it; face-parts and appendages not elevated, except the cephalic fourth of each antenna which shows a low ridge along the median line, the tubercles on the ridge causing the lateral margins of the head to appear serrate; antennae covered with minute tubercles; prothorax with a slightly elevated median ridge which is almost always lighter in color than the remainder of the segment; middle line of mesothorax usually marked by a pale yellowish line; abdominal segments 1 to 8 densely punctate, the ninth practically smooth, the tenth segment and cremaster irregularly rugose; spiracles ovate in outline, the openings elliptical; spiracular furrows of the fifth abdominal segment indistinct, very slightly elevated and interrupted by punctures; cremaster triangular, with two heavy curved spines at the distal end, each about 6 mm. long, and three hooked setae along each lateral margin.

Length 18 to 23 mm.; greatest width 7 mm.

The larvae of this species were the largest of any geometrid collected in Maine being about three inches long. They are dark brown to nearly black in color, with a prominent ridge on the mesothorax and one near the caudal end of the body. These ridges have a small orange tubercle at each side. Near the middle of the body is a very prominent brown tubercle on each side the meson, resembling the winter buds of the maple tree, so that when this larva mimics a twig, these tubercles pass for buds. They were collected from apple and maple, but are said to feed on a variety of trees. When ready to pupate, the larvae spin a few threads of silk and draw two leaves together and the pupa fastens the hooks on the cremaster into this silk. The larvae were most numerous the latter part of July, and the first one pupated August 10. The adults emerge in the spring. The pupae of this species resemble those of the genus *Sabulodes* very strongly, so no figure is shown. They differ, however, in the tubercles on the head and antennae, and in the irregularly rugose cremaster and tenth abdominal segment, and in never having any portion of the prothoracic femur exposed. The pupae of *Abbotana* never become hard and firm as most pupae do, but are always soft and yielding to the touch. They are normally much larger than those of *Sabulodes*.

Genus CLEORA Curtis.

Body of usual type; face-parts not much elevated; antennae reaching the caudal margin of the wings, the distal end of each curved slightly mesad; a small portion of the labial palpi exposed caudad of the labrum; maxillae reaching almost to the caudal margin of the wings, the proximo-lateral angles not extending quite to the eye-pieces; prothoracic legs three-fourths the length of the wings, their femora exposed; mesothoracic legs equal in length to the maxillae; mesal length of prothorax two-fifths that of the mesothorax, mesothoracic spiracle with an ovate tubercle adjacent to its caudal margin, the surface covered with fine setae; mesal length of metathorax one-fourth that of the mesothorax; first eight abdominal segments coarsely punctate; the spiracular furrow present cephalad of each spiracle on the fifth abdominal segment, the surface of the furrow very rugose; dorsal furrow never present between segments nine and ten; abdominal spiracles almost circular in outline; cremaster triangular at base, the distal half spine-like, and slightly bifurcate at tip.

This genus includes a number of species but only two are commonly found in Eastern North America. One of these *Cleora pampinaria* is described here.

CLEORA PAMPINARIA Guenée.

Fig. 2, F and I.

Color chestnut brown, usually without markings, sometimes with a few small dark spots on the appendages; face-parts and appendages almost smooth and appearing polished; prothoracic leg slightly elevated near the large exposed part of the femur; thorax smooth, or with very fine transverse impressions; abdomen densely punctate with medium punctures on the first eight segments; spiracles almost circular, the openings elliptical, that of the sixth slightly ventrad of the others; spiracular furrow (Fig. 2, I) with the surface deeply rugose, the outer edge heavily chitinized, almost black and apparently serrate; surface slightly concave between the furrow and spiracle, crossed by faint elevated lines; cremaster about 1 mm. long, the dorsal surface convex and rugose, the distal end spine-like and bifurcate.

Average length 12.5 mm.; greatest width 4 mm.

It could not be determined from the specimens whether or not there are hooked setae on the cremaster as they stayed in the soil until the moths emerged, and if present were broken off. The larvae of this species were collected from common yellow dock the latter part of June and pupated before a description was obtained. The moths emerged during September in the laboratory.

Genus DIASTICTIS Hübner.

Body of usual shape, widest in the region of the third and fourth abdominal segments; head, thorax and appendages comparatively smooth, the abdomen rather coarsely punctate; fronto-clypeal suture indicated at the base of the antennae; labrum rounded on the caudal margin; a small portion of labial palpi exposed caudad of the labrum; maxillae never quite reaching the caudal margin of the wings, the proximo-lateral angles not extending to the eye-pieces; antennae broader than the prothoracic legs, narrowed slightly at the distal end and sometimes touching on the meson; prothoracic legs three-fourths the length of the wings, their femora exposed; mesothoracic legs as long as the maxillae; tips of the metathoracic legs usually exposed caudad of the maxillae; mesal length of prothorax two-fifths that of the mesothorax; mesothoracic spiracle with a prominent ridge adjacent to its caudal margin, the edge curved slightly caudad and covered with white setae; metathorax one-half the length of the prothorax; abdominal segments 1 to 8 thickly punctate, the ninth and tenth sparsely punctate or smooth; abdominal spiracles elliptical; fifth abdominal segment with five or six shallow furrows over each spiracle, the margin of the segment cephalad of the spiracle with coarser punctures than the remainder of the segment; dorsal furrow never present between the ninth and tenth abdominal segments; cremaster rugose at base, bifurcate at the distal end.

Only two species of this genus were collected in Maine, but other species are known to occur in the State. These two species are very closely related and may be separated as follows:

a. Elevation along caudal margin of mesothoracic spiracle strongly elevated and visible in ventral view; spiracular furrows indistinct and often resembling rows of confluent punctures. *ribearia.*

aa. Elevation along caudal margin of mesothoracic spiracle strongly elevated and not visible in ventral view; spiracular furrows narrow, but distinct, the edges sharp. *anataria.*

DIASTICTIS RIBEARIA Fitch.

The Gooseberry Span-worm. Fig. 3, F, and Fig. 4, I and J.

Color dark reddish brown; head, thorax and appendages usually smooth and polished, occasionally with indeterminate transverse striations, especially on the thorax; antennae with transverse impressions indicating the segmentation, usually as long as the wings but seldom meeting on the meson; a distinct, transverse furrow present between the invaginations for the anterior arms of the tentorium; eye-pieces almost equal in width; elevation caudad of the mesothoracic spiracle prominent, and visible in ventral view, the surface thickly covered with fine whitish setae; spiracular furrows of the fifth abdominal segment indistinct and resembling confluent punctures; cremaster 1 mm. in length, rugose and bifurcate for about one-fourth its length.

Length 10 to 12 mm.; greatest width 3.5 mm.

The larvae feed on leaves of gooseberry, currant and blueberry. They are more often found on the gooseberry and often become a serious pest. The larvae are whitish, irregularly spotted with black and have yellow stripes on the dorsal and lateral aspects. They are full-grown about the last of June and enter the ground to pupate, but do not spin a cocoon. The moths emerge from the pupae in two or three weeks and lay their eggs which hatch the following spring.

DIASTICTIS ANATARIA Swett.

Fig. 4. G and H.

Color dark reddish brown, head, thorax and appendages with fine indeterminate transverse striations, but giving a smooth and polished appearance; antennae as long as the wings and meeting on the meson at their caudal margin; a transverse furrow indicated between the invaginations for the anterior arms of the tentorium, but not deep nor very distinct; eye-pieces difficult to distinguish; elevation caudad of the mesothoracic spiracle not prominent and not visible in ventral view, its surface sparsely covered with whitish setae and not very noticeable, a small furrow just caudad of the elevation; spiracular furrows of the fifth abdominal segment distinct, narrow, five or six in number and punctate at the bottom of the furrows; cremaster 1.3 mm. in length, with a distinct transverse furrow at base, rugose on the proximal half, the furrows deeper on the ventral surface, and bifurcate for one-fifth its length.

Length 10 to 12 mm.; greatest width 3.5 mm.

The larvae of this species were collected on gray birch and yellow birch. They were about an inch long, colored dull red, marked with black in an irregular marbled pattern with a whitish spot in front of each spiracle. They were collected the last week of June and were ready to pupate in about two weeks. In the laboratory they pupated on top of the soil without forming a cocoon, but would probably burrow in the soil out of doors. The adults emerged July 25.

Genus HYDRIA Hübner.

Head short, slightly narrower than the thorax; body surface slightly roughened with impressed lines and punctures, but presenting a polished appearance; epicranial suture present and distinct; labrum broader than long, rounded at the distal end; a small triangular portion of the labial palpi usually visible caudad of the labrum; maxillae sometimes reaching the caudal margin of the wings, but usually slightly shorter and exposing the tips of the metathoracic legs, the proximo-lateral angles never extending as far as the eye-pieces; antennae always reaching the caudal margin of the wings; prothoracic legs almost three-fourths the length of the wings, their femora always exposed; mesothoracic legs usually slightly shorter than the antennae; both prothoracic and mesothoracic legs extending cephalad between each sculptured eye-piece and the antenna; mesal length of prothorax two-fifths that of the mesothorax; metathorax about half the length of the prothorax and shorter than the first abdominal segment; mesothoracic spiracles slit-like; abdomen coarsely punctate, except on the ninth and tenth segments; dorsum of fifth abdominal segment with a deep furrow along the cephalic margin, invisible when the body is contracted and the movable segments telescoped; abdominal spiracles slightly produced, the openings elliptical; dorsal furrows present between the ninth and tenth abdominal segments, its caudal margin finely serrate, the lateral extension reaching caudad almost to the base of the cremaster; cremaster about twice the length of the tenth segment, a slight furrow at base, bifurcate at tip and with hooked setae near the proximal end.

HYDRIA UNDULATA Linnaeus.

The Scallop-shell Moth. Fig. 4, A and D.

Color reddish brown; ventral surface of head and appendages with shallow, impressed lines, labrum slightly elevated; thoracic segments with irregular, deeply impressed lines; metathorax and first abdominal segment showing a rather prominent ridge along the caudal margin; abdomen with the first four segments coarsely punctate except a narrow strip along the caudal margin; dorsum of fifth segment almost smooth caudad of the furrow which is edged with black; sixth, seventh and eighth segments like the first four, the ninth and tenth practically smooth; cremaster rugose at base, narrowing rapidly to a slender spine-like part which is bifurcate at tip, the arms of the bifurcation slender and divergent, lateral margin of cremaster with three slender hooked setae along each lateral margin.

Average length 9 mm.; greatest width 3 mm.

The larvae of the scallop-shell moth feed mostly on cherry. They are dark brown or nearly black on the back with some fine yellow lines, and yellowish white underneath. They make a sort of nest by webbing the leaves together at the end of a branch and adding more leaves as they need food. The larvae were collected August 26 and soon after entered the soil to pupate. They form an earthen cell in which the pupa passes the winter.

Genus PALEACRITA Riley.

Body of usual type, but usually strongly convex on the dorsum of the first three abdominal segments, so that the body is very thick in this region; face-parts decidedly elevated at the proximal ends of the antennae, clypeal region, labrum and eye-pieces; a furrow present indicating the lateral parts of the fronto-clypeal suture; labrum almost semicircular in outline; antennae reaching the caudal margin of the wings, the distal end of each curved slightly mesad; maxillae reaching the caudal margin of the wings, their proximo-lateral angles not extending as far as the eye-pieces; labial palpi never exposed; prothoracic leg reaching cephalad between the sculptured eye-piece and antenna, and at least seven-eighths the length of the wings, their femora never exposed; mesothoracic legs sometimes reaching the caudal margin of the wings, but usually a little shorter; thoracic segments unusually short, the entire thorax less than one-fourth the total length of the body; mesal length of prothorax two-thirds that of the mesothorax, and the metathorax one-half of this length; mesothoracic spiracle with its caudal margin abruptly elevated, then a gradual slope towards the base of the wing; abdomen coarsely punctate, at least on eight segments; dorsal furrow never present between the ninth and tenth segments; abdominal spiracles strongly produced, the openings somewhat lenticular; one deep spiracular furrow present over each spiracle on the fifth segment, the outer margin strongly chitinized; cremaster longer than broad, slightly bifurcate at tip often showing a fine seta on each lateral margin near the proximal end.

This genus has only one common species, *Paleacrita vernatà* which is common in the eastern part of the United States and Canada.

PALEACRITA VERNATA Peck.

The Spring Canker-worm. Fig. 3, C and D.

Color yellowish or reddish brown; head, thorax, and appendages slightly roughened with indeterminate transverse striations; a portion of the front more strongly elevated than the remainder of the face-parts; antennae showing transverse impressions; abdomen coarsely punctate on segments 1 to 8, rarely on the remaining segments; abdomen considerably arched in the region of the first three segments giving the pupa a humpbacked appearance; spiracular furrows with their transverse length twice that of the spiracles; spiracles usually black or dark brown and produced for a distance equal to their length; a prominent projection usually present on each side of the anal opening, probably the scars of the anal prolegs; cremaster less than 1 mm. in length, usually triangular at base narrowing rapidly so that the distal end is cylindrical and spine-like, slightly bifurcate at tip; lateral setae of the cremaster very fine and easily broken and not usually found on specimens.

Average length 8 mm.; greatest width 3.5 mm.; height at third abdominal segment 3 to 3.5 mm.

The larvae of the spring canker-worm are about an inch long and vary considerably in color from light brown to dull black. There is a yellow stripe running through the spiracles and a greenish yellow stripe underneath. They are ready to pupate about the first of June and enter the ground where they make an earthen cell and change to pupae. They live over winter in the pupal stage, the moths emerging in early spring. Although the female moths of this species are wingless, the pupae have the wings as well developed in the female as in the male.

Genus ERANNIS Hübner.

Cephalic half of body much thicker than the remainder, the dorsum of the first three segments convex as seen in lateral view; fronto-clypeal suture distinct for a part of its distance; clypeal and labral regions distinctly elevated, the labrum almost semi-circular in outline; labial palpi not visible; maxillae never quite reaching the caudal margin of the wings, the proximo-lateral angles never reaching the eye-pieces; antennae considerably broader than the prothoracic legs and only slightly narrowed at the distal end, always reaching the caudal margin of the wings and there curving mesad and normally touching; prothoracic legs at least seven-eighths the length of the wings, the femora never exposed, the cephalic end extending between the antenna and the sculptured eye-piece; mesothoracic legs as long as the maxillae and almost reaching the caudal margin of the wings; prothorax one-half the length of the mesothorax, the caudal margin not prominently curved at the meson; mesothoracic spiracles with a prominent ovate flattened tubercle adjacent to its caudal margin, the surface rugose and apparently covered with very fine, short setae, the tubercle extending at least one-fourth of the distance between the margin of the antenna and the meson; mesothorax shorter than usual, the metathorax about one-fourth of its mesal length; abdominal segments 1 to 8, sometimes 1 to 9, punctate, the remaining segments smooth; abdominal spiracles almost circular in outline, the openings elliptical, the lips somewhat elevated; spiracular furrows present on the fifth segment, each with a strongly chitinized edge, the surface punctate, the area surrounding the spiracle having few punctures; dorsal furrow present between the ninth and tenth abdominal segments, the edges not strongly toothed; cremaster broad at base, and rugose, narrowing rapidly to a smooth spine-like distal half which is bifurcate at tip.

ERANNIS TILIARIA Harris.

The Lime Span-worm. Fig. 3, A and B.

Color usually bright reddish or yellowish brown, the head, thorax, and appendages often darker than the remaining surface; face parts with fine indeterminate striations, almost smooth, a few wrinkles or impressed lines between the proximal ends of the antennae; thorax with shallow impressed lines; abdominal segments 1 to 8 coarsely, thickly punctate; eighth segment somewhat swollen in the region of the spiracles and narrowing rapidly to the caudal margin; caudal margin of the furrow between the ninth and tenth segments finely serrate and somewhat crenulate in outline; cremaster with a transverse furrow at base, the proximal half rugose with a slight lateral projection on each side at the base of the narrow, smooth distal portion, which is bifurcate at tip, each half slender and somewhat seta-like, very easily broken.

Average length 12 to 15 mm.; greatest width 4 to 5 mm.

The larvae of the lime span-worm were collected this season from apple, cherry, Carolina poplar and the linden or lime tree, although most of them came from apple. The caterpillars are about an inch and a half long, and the markings vary considerably. They are generally dull dark red on the back, with a broad yellow stripe through the spiracles, and whitish underneath. They were most abundant the last two weeks of June and pupated the last of June and the first week in July. They burrow into the soil near the base of the tree to pupate and make an earthen cell, but no traces of cocoons were found. The adults emerge late in the fall and lay the eggs, which do not hatch till spring.

Family NOTODONTIDAE.

The pupae of this family vary considerably, and there is no one character which will serve to separate them from those of the nearly related families. The prothoracic and mesothoracic legs are of the normal length for lepidopterous pupae, the prothoracic legs about half that of the wings and the mesothoracic legs slightly longer. The labial palpi often show a very small portion caudad of the labrum. The maxillae seldom reach the caudal margin of the wings and are usually less than three-fifths their length. The antennae are broadest at their proximal ends, and there the width exceeds that of the prothoracic legs. They seldom reach the caudal margin of the wings, and their tips often lie adjacent on the meson caudad of the other appendages. The mesothoracic leg never reaches cephalad to the eye-pieces, but the prothoracic leg always does. The latter seldom extends cephalad between the sculptured eye-piece and the antenna. The abdomen is usually punctate and only shows a dorsal furrow between the ninth and tenth segments in the genus *Datana.* The mesothoracic spiracles are usually slit-like and seldom, if ever, show an elevated ridge or tubercle adjacent to the caudal margin. The abdominal spiracles are seldom produced and always in a straight line. Spiracular furrows are never present. A few members of this family have no cremaster, but usually a short cremaster is present. The presence of hooked setae on the cremaster is the exception in the Notodontidae, as most of them pupate in the ground.

The colors vary but little in this family, nearly all being chestnut-brown, but a few are nearly black. None of the species known have prominent markings on the body. The genera of Notodontidae may be separated as follows:

a. Maxillae one-third or less the length of the wings; both prothoracic and mesothoracic legs meeting on the meson caudad of the maxillae; abdomen very finely punctate.
  b. Thorax and abdomen thickly covered with very fine short setae; cremaster a stout spine about one millimeter in

length with two short recurving hooks at the tip, each of which bears two or more very fine setae. *Melalopha.*

bb. Thorax and abdomen never thickly covered with very fine, short setae; cremaster never as described above; sometimes absent.

c. Abdominal segments 2 to 7 with a slight ridge at both cephalic and caudal margins, the cephalic ridge interrupted by deep pits giving it the appearance of a row of square tubercles; face-parts and appendages not elevated, making a smooth even surface; cephalic end of body not elevated between the antennae; cremaster short. *Apatelodes.*

cc. Abdominal segments 2 to 7 never with ridges; appendages distinctly elevated; cephalic end of body elevated between the antennae; cremaster never present. *Harpyia.*

aa. Maxillae always more than one-third the length of the wings; never with both prothoracic and mesothoracic legs meeting on the meson; abdomen usually rather coarsely punctate.

b. Maxillae from one-half to three-fifths the length of the wings; mesothoracic legs meeting on the meson caudad of the maxillae; appendages roughened with deep indeterminate striations; abdomen coarsely punctate; a distinct, deep furrow on the dorsum between the ninth and tenth abdominal segments; cremaster short, bifurcate, each half with several short, spiny projections. *Datana.*

bb. Maxillae more than three-fifths the length of the wings; neither prothoracic nor mesothoracic legs meeting on the meson caudad of the maxillae; appendages usually with shallow striations; a distinct furrow never present on the dorsum between the ninth and tenth abdominal segments; cremaster not as described above.

c. Entire body surface with coarse deep punctures; cephalic margin of the movable abdominal segments with large lunate punctures and a ridge with a row of large distinct punctures just caudad of it; cremaster short, rugose, slightly bifurcate; bearing six long hooked setae; mesothorax never with a deeply pitted caudal margin. *Symmerista.*

cc. Body usually punctate on the abdomen but not on the appendages; movable abdominal segments sometimes with a slight ridge along the cephalic margin but never with a row of large punctures just caudad of it; cremaster bifurcate, but never with hooked setae; mesothorax with a row of deep pits along the caudal margin, with smooth quadrangular areas between and partly covering them.

d. Wings always touching on the meson; maxillae never as long as the wings; cephalic end of body sometimes with two sharp, heavily chitinized projections. *Schizura.*

dd. Wings adjacent on the meson but not touching; maxillae usually as long as the wings; cephalic end of body never with heavily chitinized projections. *Heterocampa.*

Genus MELALOPHA Hübner.

Body cylindrical, blunt at the cephalic end, the head scarcely visible in dorsal view; surface smooth, polished, covered with very fine setae which are only visible by the aid of a lens; epicranial suture present but only a small portion visible, the vertex being represented by a small triangular area adjacent to each antenna; labrum usually broader than long; sculptured eye-piece more than twice the width of the glazed eye-piece; antennae broader at the proximal end than the prothoracic legs and tapering gradually to a pointed tip; labial palpi usually entirely concealed, but occasional specimens show a small portion just caudad of the labrum; maxillae one-third or less the length of the wings, the proximo-lateral angles never reaching the eye-pieces; legs of the normal length, both prothoracic and mesothoracic legs adjacent on the meson caudad of the maxillae, and a very small portion of the metathoracic legs showing between the wings at their caudal margin; thorax relatively short, only about one-fourth the length of the body; mesal length of prothorax two-fifths that of the mesothorax; metathorax shorter than the first abdominal segment; spiracles all slightly elevated, their openings elliptical; abdomen finely punctate; cremaster a straight spine with the distal end widened and bearing two or three recurving hooks on each side, each hook bearing minute setae on its mesal margin which are very easily destroyed.

MELALOPHA INCLUSA Hübner.

Fig. 5, C and I.

Color usually yellowish brown, with darker brown on the thorax, the cephalic margin of the abdominal spiracles, the cephalic margin of the movable abdominal segments and the cremaster; antennae smooth, ending opposite the prothoracic legs; maxillae one-third the length of the wings or slightly less; first three segments of the abdomen usually more elevated than the thorax and forming a distinct curve; abdominal segments finely punctate, the cephalic margin of each movable segment much more densely punctate, the ninth and tenth segments almost smooth; first abdominal segment with the scar of the larval tubercles apparent, in some specimens as a dark spot on each side of the meson, in others a small, but distinct tubercle in the same position; cremaster (Fig. 5, I) 1 mm. in length, with either two or three recurving hooks on each side.

Length 13 to 16 mm.; greatest width 5 mm.

The larvae of this species feed on poplar. Several of the larvae live together in a sort of tent formed by drawing two or three leaves together with threads of silk. They spin a loose cocoon, placing it among the leaves in captivity, but no cocoons were found during the summer's collecting.

Genus APATELODES Packard.

Cephalic half of body to the caudal margin of the wings wider and thicker than the caudal half, which tapers gradually to the short blunt cremaster; body surface highly polished, none of the face-parts or appendages prominently elevated so that the surface is smooth and even; epicranial suture present, but faint; vertex about twice as long at lateral margin as at meson; fronto-clypeal suture sometimes indicated by an impressed line; cephalic margin of labrum about twice the width of the caudal margin; labial palpi represented by a small pentagonal area just caudad of the labrum; antennae broader at the proximal end, where they slightly exceed the width of the prothoracic legs, and tapering gradually to a pointed tip; maxillae one-third the length of the wings, their proximo-lateral angles separated from the eye-pieces by almost the width of the latter; legs of about the usual length, the prothoracic legs adjacent on the meson caudad of the maxillae for a distance equal to the length of the maxillae; mesothoracic legs meeting just caudad of the prothoracic ones; wings adjacent on the meson for a short distance caudad of the mesothoracic legs; mesal length of the prothorax slightly more than half that of the mesothorax which is shorter than usual in the notodontids; metathorax equal in length to the first abdominal segment; abdomen very finely, sparsely punctate, some of the segments with a flanged plate or ridge along the cephalic margin which is interrupted by deep pits, segments 4 to 6 with a similar plate along the caudal margin not interrupted by pits; cremaster, if present, very short, rough, and usually blunt.

APATELODES TORREFACTA Smith and Abbot.

Fig. 6, G.

Color very dark reddish brown; head usually smooth and highly polished, sometimes roughened around the labrum; antennae ending slightly cephalad of the prothoracic legs; thorax with a few impressed lines and punctures; prothorax always with a small group of punctures in the caudo-lateral angle near the spiracle; mesothoracic spiracle with an elevated caudal margin and caudad of this a slight depression; abdominal segments 2 to 7 with an elevated cephalic ridge interrupted by pits, and sparsely covered with very fine punctures and a few striations in the spiracular region; segments 8 to 10 with a very few punctures; cremaster very short, less than 1 mm., rugose and scarcely bifurcate at tip.

Length 20 to 22 mm.; greatest width 9 mm.

The larva of this species has been taken in Maine on ash, beach, plum, oak, sassafras and various species of Rubus. It is very hairy, somewhat like a "woolly bear" and light grey in color with two long pencils of hairs on the thorax and one on the eighth abdominal segment. It enters the ground to pupate and there makes an earthen cell. The pupa is easily recognized by the peculiar "bordered" appearance of the abdominal segments.

Genus HARPYIA Ochsenheimer.

Body distinctly depressed, elliptical in outline; front elevated at meson to accommodate the slight crest of the adult; frontoclypeal suture indicated laterad by a slight furrow; invaginations for the anterior arms of the tentorium large and distinct; clypeolabral suture indicated by a furrow; labrum nearly as long as broad, the caudal margin slightly narrowed; genae elevated; antennae elevated with the proximal half almost twice the width of the prothoracic legs, then rapidly narrowing to about one-fourth of this width, ending slightly caudad of the prothoracic legs; maxillae one-third the length of the wings; prothoracic and mesothoracic legs of the usual length and both meeting on the meson caudad of the maxillae; wings meeting on the meson caudad of the mesothoracic legs; mesal length of the prothorax slightly more than half that of the mesothorax, and that of the metathorax one-sixth that of the mesothorax; abdominal segments punctate; no cremaster present.

HARPYIA BOREALIS Boisduval.

Fig. 5, J.

Color reddish or yellowish brown; surface smooth and dull; head, thorax and appendages with fine striations more prominent on the prothorax and front; antennae with a row of minute tubercles along the middle line; maxillae with the proximolateral angles separated from the eye-pieces by a distance equal to the width of the eye-pieces; prothorax with a protuberance at each cephalo-lateral angle, probably indicating the scar of larval protuberances; mesothoracic spiracle slit-like; abdomen finely, sparsely punctate on the dorsum of the first eight segments, the remainder of the surface smooth; spiracles lenticular, usually margined by a black line.

Length 16 to 18 mm.; greatest width 7 mm.

The larvae of this species have been taken in Maine from poplar.

The larvae of this species belong to the group popularly known as horntails, on account of the long tail-like projections from the caudal end of the body. *Harpyia borealis* has two of these. The body is yellowish in color, the dorsal part nearly all dark brown. They feed on wild cherry. The larvae are found early in September and pupate about the last of the month. The cocoon is very thick and tough and usually spun against the side of the tree, where it resembles an excrescence on the bark.

Genus DATANA Walker.

Body always with an elevation at the cephalic end between the proximal ends of the antennae evidently to accommodate the crest of the imago; front prominently elevated, the elevation roughened with deep transverse striations and deeply punctate along the lateral margins; labrum also elevated, more prominently on the cephalic half; mandibular area sometimes elevated; glazed eye-piece always very narrow, scarcely more than a line along the mesal margin of the sculptured eye-piece; antennae at proximal end wider than the prothoracic legs and tapering gradually to a pointed tip, usually about two-thirds the length of the wings; maxillae from one-half to three-fifths the length of the wings, the proximo-lateral angles extending to the eye-pieces; labial palpi entirely concealed; legs of the usual length, the mesothoracic pair always meeting on the meson caudad of the maxillae; wings always adjacent on the meson caudad of the mesothoracic legs; mesothorax shorter than usual so that the thoracic segments are only one-fourth the total length of the body; mesal length of the prothorax one-half that of the mesothorax, the metathorax about one-sixth of the same length; thorax and abdomen always punctate; dorsum of abdomen always showing a deep furrow between segments nine and ten, its caudal margin serrate; cremaster short, bifurcate, each half bearing two or more short spinous projections.

There are at least four species of *Datana* found in Maine, and two of these *Datana ministra* and *Datana integerrima* may become serious pests. The other two species are comparatively rare as far as our records for the state show. While the pupae of this genus are very distinctive, the species are very closely related and the characters available for their separation are somewhat variable. The teeth on the furrow between the ninth and tenth abdominal segments vary considerably, but in general follow the same arrangement. The following table may serve to separate the species:

a. Prothoracic legs always extending as far caudad as the maxillae, or meeting on the meson caudad of them; furrow between the ninth and tenth abdominal segments with the teeth on the caudal margin all short and approximately of equal length; pupae normally less than 20 mm. in length.

  b. Dorsum of tenth abdominal segment not punctate; caudal margin of the furrow between the ninth and tenth abdominal segments scarcely elevated; surface usually shining and polished. *angusii.*

  bb. Dorsum of tenth abdominal segment punctate as the remaining segments except perhaps a small area near meson; caudal margin of the furrow between the ninth and tenth abdominal segments always considerably elevated; surface dull. *integerrima.*

aa. Prothoracic legs not extending as far caudad as the maxillae, at least 1 mm. apart; furrow between the ninth and tenth abdominal segments with the teeth on the caudal margin uneven, and longer near the meson; pupae normally over 20 mm. in length.

  b. Crest on the front with a prominent longitudinal carinate ridge on the meson and a distinct furrow on each side; abdomen with medium punctures; each half of the cremaster with three projections. *major.*

  bb. Crest on the front without longitudinal ridges or furrows; abdomen with large shallow punctures; each half of the cremaster with two projections. *ministra.*

DATANA ANGUSII Grote and Robinson.

Fig. 5, D and E.

Color bright reddish brown; crest prominent, always rugose with deep transverse striations and punctures, and usually with two longitudinal furrows; face-parts and appendages with transverse striations, much shallower than those of the crest and not noticeably punctate; antennae ending just cephalad of the mesothoracic legs; maxillae slightly more than half the length of the wings, usually about four-sevenths; prothoracic legs normally ending opposite the maxillae; cephalic margin of prothorax considerably elevated as seen in lateral view; prothorax with a distinct median carinate ridge, a similar but less prominent ridge on the metathorax; abdomen with medium punctures, larger along the cephalic margin of the movable segments; the surface irregular with fine ridges and some irregular depressions so that it does not appear even; first three abdominal segments broadly elevated along the meson; furrow between the ninth and tenth abdominal segments without prominent teeth, the teeth all about the same size; ninth abdominal segment with few punctures, the tenth smooth; each half the cremaster (Fig. 5, E) with a large, rather blunt mesal projection and a smaller, more pointed lateral one.

Length 15 to 18 mm.; greatest width 5 mm.

The larvae of this species feed on walnut and hickory. They pupate in the ground, each larva making a somewhat oval cell, without spinning a cocoon.

DATANA MAJOR Grote and Robinson.

Fig. 5, F.

Color bright reddish brown; crest very prominent with two longitudinal furrows and deep transverse striations, the lateral margins punctate; face-parts and appendages with irregular, transverse striations and depressions; antennae meeting on the meson caudad of the mesothoracic legs; maxillae slightly more than half the length of the wings; prothoracic legs much shorter than the maxillae; mesothoracic legs meeting on the meson just caudad of the maxillae; cephalic margin of prothorax not elevated; prothorax and metathorax very slightly elevated along the meson; abdomen rather coarsely punctate and with small indeterminate depressions, both transverse and longitudinal; furrow between the ninth and tenth segments edged with black, the caudal margin elevated and with uneven teeth; both ninth and tenth abdominal segments punctate like the remaining segments; each half of the cremaster (Fig. 5, F) with three equal projections.

Length 25 to 27 mm.; greatest width 8 mm.

The larvae of this species feed on certain species of Vaccinium, the common blueberries and deerberry, also on Andromeda. As its name implies it is the largest species of the genus. The method of pupation is probably the same as for the other species of *Datana*, but it has not been observed by the writer.

DATANA INTEGERRIMA Grote and Robinson.

Fig. 5, G.

Color dark brown; crest not very prominent, the longitudinal furrows not deep or well defined; face-parts and appendages very rough with impressed lines and other surface sculpturing; antennae never meeting on the meson nor extending as far caudad as the mesothoracic legs; maxillae about one-half the length of the wings and slightly longer than the prothoracic legs; mesothoracic legs meeting on the meson caudad of the maxillae; median line of the prothorax and metathorax slightly elevated; thorax noticeably punctate among the transverse striations; abdominal segments rather finely punctate, with few other markings; furrow between the ninth and tenth segments edged with black, the caudal margin elevated and almost evenly toothed; both ninth and tenth abdominal segments punctate; each half of the cremaster with three short, almost equal projections.

Length 17 to 19 mm.; greatest width 6 mm.

The larvae of this species feed on walnut, hickory and oak. They are found in large companies and always keep together while feeding. They pupate in the ground.

DATANA MINISTRA Walker.

Fig. 5, H.

Color bright reddish brown, sometimes yellowish brown; crest on front seldom showing longitudinal furrows; face-parts and appendages rugose with indeterminate transverse striations, the appendages less rugose than the face-parts; maxillae three-fifths the length of the wings or a trifle shorter, always longer than the prothoracic legs; cephalic margin of prothorax slightly elevated; median line of prothorax and metathorax slightly elevated but not carinate; abdomen coarsely punctate, the punctures larger along the cephalic margin of each movable segment, and with scarcely any other markings; furrow between segments nine and ten edged with black, the teeth coarse and largest near the meson; caudal margin of furrow elevated; eighth and ninth abdominal segments always punctate; cremaster usually with two short spinous projections on each half.

Length about 23 mm. varying but little; greatest width 7 mm.

Most larvae of *Datana ministra* have been collected from apple in this state, although it feeds on a variety of other trees. The larva enters the ground to pupate. It spins no cocoon, but forms an earthen cell in which silk threads are seldom present.

Genus SYMMERISTA Hübner.

Head distinctly narrower than the thorax; body surface punctate, even on the appendages, though presenting a polished appearance, and without impressed lines or other markings; clypeal region slightly elevated; invaginations for the anterior arms of the tentorium very distinct; labrum almost semicircular in outline; glazed eye-piece one-fourth the width of the sculptured eye-piece and bounded mesally by an impressed black line; maxillae about nine-tenths the length of the wings, the tips of the antennae meeting just caudad of them on the meson; antennae considerably wider at the proximal end, but their greatest width is not equal to that of the prothoracic leg; prothoracic and mesothoracic legs of the usual length, never meeting on the meson; wings meeting on the meson for a short distance caudad of the antennae; mesal length of prothorax one-third that of the mesothorax and the metathorax one-fourth of the same length; cremaster short, slightly bifurcate, and bearing hooked setae.

SYMMERISTA ALBIFRONS Smith and Abbot.

Fig. 6, A and B.

Color dark chestnut-brown; mesal half of the genae and a small area adjoining the cephalic margin of the prothorax highly polished and without punctures; punctures on the front black, and more irregular in outline than on the remainder of the body surface; mesothoracic spiracles with both margins elevated, the caudal margin slightly more so than the cephalic, and black in color; movable abdominal segments with the cephalic margin more densely punctate than the remainder and with large lunate punctures; cephalic margin separated from the remainder of the segment by a distinct ridge, and just caudad of this a row of large black punctures; abdominal spiracles (Fig. 6, B) elevated along the cephalic margin, the openings somewhat crescent-shaped and directed caudad; cremaster less than 1 mm. in length, rugose with longitudinal ridges, each point of the bifurcation bearing three hooked setae.

Length 17 to 21 mm.; greatest width 5 to 7 mm.

The larvae of *Symmerista albifrons* are striped longitudinally with black and red and have a prominent red hump near the caudal end of the body. They spin a thin, tough cocoon between leaves, and are usually found on the surface of the ground under the tree on which the larvae fed. The larvae feed on oak and maple. They appear late in the season and pupate in September.

Genus SCHIZURA Doubleday.

Body of usual type, sometimes with a projection at the cephalic end; surface appearing smooth and polished; epicranial suture visible in some species; antennae with the greatest width greater than that of the prothoracic legs, narrowed rapidly and forming a long pointed tip, never quite reaching the caudal margin of the wings; maxillae always more than three-fifths the length of the wings, but never reaching their caudal margin, the caudo-lateral angles always reaching the glazed eye-piece, sometimes extending beyond; mesal length of prothorax one-half that of the mesothorax; mesonotum with a row of deep elongate pits along the caudal margin of the wings with smooth, square black areas between; metathorax with its mesal length about one-fourth that of the mesothorax; abdomen with the first eight segments punctate; cremaster entirely bifurcate, each half somewhat boot-shaped, the lateral margins of the cremaster subparallel.

The species of Schizura may be separated by the following table:

a. Maxillae always more than seven-eighths the length of the wings; cephalic end of body blunt and only slightly projecting between the antennae; abdominal segments 5 to 7 with the punctures distinctly larger and more numerous along the cephalic margin; body never with prominent tubercle scars on the dorsum of the mesothorax, metathorax, and first abdominal segments. *ipomeae.*

aa. Maxillae five-sixths the length of the wings; cephalic end of body with a prominent, slightly bifurcate projection; abdominal segments 5 to 7 with the punctures of approximately the same size and not much more numerous along the cephalic margin; body with prominent tubercle scars on the dorsum of the mesothorax, metathorax and first abdominal segment. *concinna.*

SCHIZURA IPOMEAE Doubleday.

Fig. 5, B.

Color bright yellowish brown; body with a slight projection at the cephalic end between the proximal ends of the antennae; epicranial suture visible for a short distance adjacent to each antenna in the majority of specimens; face-parts and appendages smooth and polished, with very few punctures or other surface markings; mandibular area slightly elevated; antennae ending just caudad of the mesothoracic legs, but never meeting on the meson; maxillae more than seven-eighths the length of the wings, the caudo-lateral angles always extending to the eye-pieces; sculptured eye-piece distinguished by its impressed lines and slightly wider than the other; thoracic segments with a few fine punctures; mesothorax without punctures as in *S. concinna*, but with short, transverse, impressed lines on each side the meson; caudal margin of mesonotum with seven pits and six square black polished areas between; abdominal segments sparsely covered with very fine punctures except for a band along the cephalic margin of segments 5 to 7, which is densely and rather coarsely punctate; first abdominal segment often with a small rounded tubercle, or at least a tubercle scar on the meson showing the location of the prominent larval projection; abdominal spiracles slightly produced, the openings somewhat crescent-shaped; eighth abdominal segment with a dark tubercle scar on each side of the meson; cremaster about 1 mm. in length, the lateral margins subparallel, the mesal margins with two projections.

Length 15 to 20 mm.; greatest width 4 mm.

The larvae of this species has been collected only on maple, although it is reported from oak, elm and several other trees. The larvae enter the soil to pupate and there spin a thin cocoon which is covered with particles of sand or soil. The pupae of this species closely resemble those of certain species of *Heterocampa* notably *H. bilineata.*

SCHIZURA CONCINNA Smith and Abbot.

The Red-humped Apple-worm. Fig. 5, A.

Color chestnut brown; body with a prominent median cephalic projection which is slightly bifurcate; face-parts and appendages smooth and polished, without markings except for a few transverse impressions; antennae not extending as far caudad as the mesothoracic legs, which are usually 1 mm. longer; maxillae five-sixths the length of the wings; scars of larval projections prominent on each side the meson of the mesothorax, metathorax and first abdominal segment, where they often show as distinct tubercles, less prominent scars on the fourth abdominal segment, and occasionally scars visible on the other segments but usually not distinct; caudal margin of mesonotum normally with nine pits and eight square, black, polished areas between; abdominal segments rather densely punctate with punctures of medium size, the punctures on the cephalic margin of segments 5 to 7 differing very little from those on the remainder of the segment; abdominal spiracles large, slightly produced, the openings elliptical, the margins very dark brown; cremaster about one-half millimeter in length, bifurcate, each half oblong with a very slight projection at each angle and another on the mesal margin about half way to the distal end.

Length 10 to 12 mm.; greatest width 4 mm.

The red-humped apple caterpillar is often a serious pest in apple orchards. It also feeds on other fruit trees and a number of forest trees. The larvae feed mostly at the ends of the branches and live in colonies. They have fine black and white longitudinal stripes on the body and near the cephalic end some short black projections with a prominent reddish hump on the fourth abdominal segment. They usually pupate under dead leaves and sticks at the base of the tree and begin to pupate the last of August or in the early part of September. They spin a very thin cocoon which is usually fastened between two dead leaves or some small sticks. There is only one brood in Maine and adults emerge from these pupae the following spring.

Genus HETEROCAMPA Doubleday.

Body slightly wider at the cephalic half, tapering gradually from the fourth abdominal segment to the cremaster; fronto-clypeal suture faintly indicated; labrum somewhat triangular in outline, much narrower on the caudal margin; glazed eye-piece about one-half the greatest width of the sculptured eye-piece; antennae more than seven-eighths the length of the wings; maxillae usually as long as the wings, but sometimes a little shorter, the proximo-lateral angles extending laterad to the eye-pieces; prothoracic and mesothoracic legs visible and of the usual length; labial palpi never visible; wings adjacent on the meson below the maxillae but seldom touching; mesal length of prothorax about two-fifths that of the mesothorax; mesonotum with a row of deep pits along the caudal margin separated by smooth quadrangular areas; mesal length of metathorax one-fifth that of the mesothorax; abdominal segments punctate; cremaster bifurcate, each half somewhat boot-shaped.

HETEROCAMPA GUTTIVITTA Walker.

The Saddled Prominent. Fig. 6, C and D.

Color very dark brown, often almost black; surface smooth and polished; head, thorax and appendages slightly roughened with fine, rather close striations excepting the genae and glazed eye-pieces which are highly polished; maxillae slightly longer than the antennae but never quite reaching the caudal margin of the wings; pits along the caudal margin of the mesonotum normally eight, but occasionally with only seven; mesothoracic spiracle with a smooth, slightly elevated area adjacent to its caudal margin which has a small semicircular depressed area in the middle; abdomen finely but not coarsely punctate, the punctures slightly larger along the cephalic margin of the segments; spiracles lenticular, slightly depressed; cremaster with the lateral margins subparallel, usually 1 mm. in length, sometimes shorter; a rugose area at base bounded cephalad by a narrow, irregular carinate ridge.

Length 18 to 22 mm.; greatest width 6 mm.

The larvae of this species feed on beech, maple, and many other trees. They often become very numerous and during the years 1908 and 1909 became a serious pest in Maine and New Hampshire. A description of the larvae and their life history is given in Bulletin 161 of the Maine Agricultural Experiment Station. The larvae when full grown pupate in an earthen cell, or among leaves at the base of the trees.

HETEROCAMPA BILINEATA Packard.

Color usually chestnut brown, sometimes darker; surface smooth and polished; head, thorax and appendages almost smooth, with a few slightly depressed lines; maxillae always reaching the caudal margin of the wings; pits along the caudal margin of the mesonotum usually eleven, occasionally only ten; mesothoracic spiracle with a very narrow elevation adjacent to the caudal margin, and caudad of this a slight depression; abdomen rather coarsely punctate on the cephalic margin, the punctures smaller and farther apart on the remainder of the segment; abdominal spiracles lenticular but not depressed; cremaster with the lateral margins distinctly converging to the tip, usually less than 1 mm. in length, never with a rugose area at base.

Length 16 to 20 mm.; greatest width 5 mm.

The larvae of this species have been collected in Maine from oak, elm and linden. The larva enters the soil to pupate, where it spins a loose web of silk to which the particles of soil adhere, forming a sort of earthen cocoon.

Family PLATYPTERYGIDAE.

This family consists of four genera, and pupae of only two of these have been seen. The larvae of *Oreta rosea* were collected, but were not reared to maturity. The pupae of the two genera vary considerably in some respects, but are very similar in others. They have the maxillae very short, about one-third the length of the wings. The legs are of normal length, both the prothoracic and mesothoracic meeting on the meson caudad of the maxillae. The antennae are about the width of the prothoracic legs at their proximal end and are gradually narrowed towards the tip. They are slightly longer than the mesothoracic legs. The tips of the metathoracic legs are always exposed. The metathoracic wings are always visible on the ventral surface of the body. They meet on the meson caudad of the mesothoracic legs and then separate to show the metathoracic legs. They are also visible along the caudal margin of the mesothoracic wings. The thorax is of normal length and the mesothoracic spiracles are slit-like. The abdomen is punctate, with a dorsal furrow present between the ninth and tenth segments. This furrow is never as well-defined as in the Geometridae. The abdominal spiracles are usually quite large and in a straight line. No spiracular furrows are present. A cremaster is always present and may or may not have hooked setae.

So far as known the members of this family do not pupate in the ground, but in a thin cocoon, or attached to a web of silk by the cremaster. The genera described here may be separated as follows:

a. Cremaster with prominent hooked setae; prothorax with a prominent median ridge which shows as a median cephalic projection on the ventral surface; body densely covered with whitish bloom. *Falcaria.*

aa. Cremaster without prominent hooked setae; prothorax without a prominent median ridge, the front having two prominent cephalic projections; body never with bloom on any part of its surface. *Drepana.*

Genus FALCARIA Haworth.

Body of usual shape, and densely covered with a whitish bloom; face-parts slightly elevated, an irregular tubercle on the front adjacent to the proximal end of each antenna; caudal portion of the clypeal region distinctly elevated to form a large rounded tubercle; prothoracic leg extending cephalad between the sculptured eye-piece and the antenna; antennae about seven-eighths the length of the wings, the distal end of each curved slightly laterad, widest at the cephalic end where they exceed the greatest width of the prothoracic legs and narrowed gradually to half this width at the distal end; maxillae slightly more than one-third the length of the wings, the proximo-lateral angles never extending to the eye-pieces; labial palpi entirely concealed; prothoracic legs three-fifths the length of the wings, the distal third of their length meeting on the meson caudad of the maxillae; mesothoracic legs about five-sixths the length of the wings, and meeting on the meson caudad of the prothoracic legs for about the same distance; tips of the metathoracic legs showing on the meson between the wings; metathoracic wings exposed on the ventral surface, meeting on the meson just caudad of the mesothoracic wings and extending along the mesal margin of the mesothoracic wings to their caudal margin, and visible most of the way across to the lateral margin; prothorax with a prominent ridge on the meson, visible in ventral view; mesal length of prothorax two-fifths that of the mesothorax; mesothoracic spiracles slit-like; metathorax shorter than usual, its mesal length one-sixth that of the mesothorax; abdominal segments 1 to 8 with medium sized punctures and sparsely covered with small curved spines which are more numerous near the spiracles and the scars of the ventral prolegs, the transverse conjunctiva covered with small spines or spinous processes; body setae arising from the bases of the larger spines; dorsal furrow present between the ninth and tenth segments; abdominal spiracles slightly sunken, lenticular in outline, the openings elliptical; cremaster triangular in outline, longer than broad and ending in a group of stout hooked setae.

This genus includes a single species, *Falcaria bilineata*, found throughout the Atlantic states.

FALCARIA BILINEATA Packard.

Fig. 6, F and H.

Color dark brown, but covered with dense, rather flocculent, whitish bloom; head, thorax and appendages considerably roughened with indeterminate, transverse impressed lines; labrum somewhat quadrangular, the caudal margin slightly notched;

clypeal region elevated to form a prominent quadrangular tubercle bearing two prominent setae; tubercle at the proximal end of each antenna also bearing prominent setae; antennae tuberculate, the three rows of tubercles arranged transversely; surface of thorax more roughened than that of the head and with a small, irregular tubercle at the base of each important seta; dorsal furrow between the ninth and tenth abdominal segments distinct, the caudal margin not more strongly chitinized and toothed as in the Geometridae; tenth segment (Fig. 6, F) with a distinct V-shaped depression at the proximal end of the cremaster, the triangular area between considerably more elevated than the remainder of the segment; cremaster triangular in outline, rugose, the lateral margins convex, and narrowed to a rounded tip, then flaring suddenly on each side to form a spiny process which is much shorter than the stout curved setae; four stout hooked setae inserted at the meson at the caudal end of the cremaster and one inserted on each side on the ventral surface just caudad of the lateral projections of the cremaster.

Length about 12 mm.; greatest width 4 mm.

The larvae of this species were collected on the leaves of gray birch June 26. They are peculiar in that they have no well developed anal prolegs. The last segment bears a cylindrical projection which sticks up and away from the surface of the leaf. The body is roughened and somewhat granular with some wart-like projections on the mesothorax and metathorax and the second abdominal segment. The colors are yellowish or golden brown, with darker brown markings. They spin a thin yellowish cocoon which is usually fastened to the under side of the leaf. Often the leaf is curled over the cocoon so as to conceal it. The pupae are at first a bright yellow brown, but after a day turn dark brown and the bloom appears. The adults emerged July 23.

Genus DREPANA Schrank.

Body of usual shape with two prominent cephalic projections; face-parts not prominently elevated, the labrum being slightly more convex than the remainder; eye-pieces reached only by the prothoracic leg which extends for a short distance between the sculptured eye-piece and the antenna; antennae about four-fifths the length of the wings, widest at the proximal end, where they equal the width of the prothoracic legs; tapering gradually to a pointed tip; maxillae about one-third the length of the wings, the proximo-lateral angles never extending to the eye-pieces; labial palpi entirely concealed; prothoracic legs almost three-fifths the length of the wings, meeting on the meson caudad of the maxillae, for about two-fifths of their length; mesothoracic legs a little shorter than the antennae, meeting on the meson for about the same distance as the prothoracic legs; tips of metathoracic legs exposed between the metathoracic wings; metathoracic wings meeting on the meson caudad of the mesothoracic legs and extending along the mesal margin of the mesothoracic wings to their caudal margin, below which they are visible for the greater part of their length; mesal length of prothorax two-fifths that of the mesothorax; mesothoracic spiracles slit-like; metathorax short, its mesal length only one-third that of the prothorax; abdominal segments 1 to 8 punctate, the punctures thickest along the cephalic margin of the movable segments; abdominal spiracles lenticular in outline, the openings elliptical; cremaster triangular, the distal end widened out and somewhat spherical.

This genus includes but one eastern species *Drepana arcuata* which is found throughout the Atlantic States.

DREPANA ARCUATA Walker.

Fig. 6, E.

Color on head, thorax, and appendages dark brown except the tips of the cephalic projections which are reddish brown, the abdomen dull green mottled with dark brown, the coloring darkest on the dorsum; head, thorax and appendages considerably roughened with indeterminate transverse impressed lines; cephalic projections triangular, their tips slightly curved dorsad, situated on the front adjacent to the proximal ends of the antennae; glazed eye-pieces, clypeus and front smooth and polished; thoracic segments with a slightly carinate median line; abdomen with the first eight segments punctate, the remainder smooth; dorsal furrow between the ninth and tenth segments not distinct forming an indistinct V-shaped depression at the base of the cremaster; cremaster slightly rugose, the basal part triangular, then a narrow, cylindrical portion which expands into a wider, knob-like end with a row of inconspicuous projections on the dorsal surface.

A pupa of this species was collected from white birch, August 3. The cremaster was entangled in a web of silk on the underside of a leaf, but there was no cocoon present. The adult emerged August 15.

The larvae of these are dark red above and have a pair of prominent tubercles on the first abdominal segment.

LIST OF ABBREVIATIONS.

a.	antennae
a1-a10.	abdominal segments 1-10.
ao.	anal opening.
at.	invaginations for the anterior arms of the tentorium.
cl.	clypeus.
cm.	cephalic margin of an abdominal segment.
cr.	cremaster.
es.	epicranial suture.
f.	front.
f 1.	femur of the prothoracic leg.
ge.	glazed eye-piece.
go.	genital opening.
lb.	labrum.
1_1	prothoracic leg.
2_2	mesothoracic leg.
3_3	metathoracic leg.
lp.	labial palpi.
ms.	mesothorax.
msp.	mesothoracic spiracle.
mt.	metathorax.
mx.	maxillae.
p.	prothorax.
s.	spiracle.
se.	sculptured eye-piece.
sf.	spiracular furrow.
ts.	tubercle scar.
v.	vertex.
w 1.	mesothoracic wing.
w 2.	metathoracic wing.

Fig. 2, A to I.

A Hypothetical pupa, ventral view.
B Hypothetical pupa, dorsal view.
C *Cosymbia lumenaria,* ventral view, female.

D *Sicya macularia,* ventral view, male.
E *Ania limbata,* ventral view, male.
F *Cleora pampinaria,* ventral view, female.
G *Sicya macularia,* dorsal view of tenth segment and cremaster.
H *Ania limbata,* dorsal view of tenth segment and cremaster.
I *Cleora pampinaria,* spiracle and spiracular furrow.

Fig. 3, A to F.

A *Erannis tiliaria,* dorsal view.
B *Erannis tiliaria,* ventral view, male.
C *Paleacrita vernata,* ventral view, female.
D *Paleacrita vernata,* lateral view.
E *Aplodes mimosaria,* ventral view, female.
F *Diastictis ribearia,* ventral view, male.

Fig. 4, A to K.

A *Hydria undulata,* ventral view, male.
B *Sabulodes lorata,* ventral view, female.
C *Cingilia catenaria,* ventral view, female.
D *Hydria undulata,* dorsal view of fifth abdominal segment.
E *Sabulodes lorata,* dorsal view of tenth segment and cremaster.
F *Cingilia catenaria,* dorsal view of tenth segment and cremaster.
G *Diastictis anataria,* dorsal view of cremaster.
H *Diastictis anataria,* ventral view of cremaster.
I *Diastictis ribearia,* dorsal view of cremaster.
J *Diastictis ribearia,* ventral view of cremaster.
K *Sabulodes transversata,* dorsal view of tenth segment and cremaster.

Fig. 5, A to J.

A *Schizura concinna,* ventral view, female.
B *Schizura ipomeae,* dorsal view.
C *Melalopha inclusa,* ventral view, female.
D *Datana angusii,* ventral view, male.
E *Datana angusii,* dorsal view of tenth segment and cremaster.
F *Datana major,* dorsal view of tenth segment and cremaster.
G *Datana integerrima,* dorsal view of tenth segment and cremaster.
H *Datana ministra,* dorsal view of tenth segment and cremaster.
I *Melalopha inclusa,* cremaster.
J *Harpyia borealis,* ventral view, male.

Fig. 6, A to H.

A *Symmerista albifrons,* ventral view, male.
B *Symmerista albifrons,* abdominal spiracle.
C *Heterocampa guttivitta,* ventral view, female.
D *Heterocampa guttivitta,* dorsal view.
E *Drepana arcuata,* ventral view, female.
F *Falcaria bilineata,* dorsal view of tenth segment and cremaster.
G *Apatelodes torrefacta,* ventral view, male.
H *Falcaria bilineata,* ventral view, female.

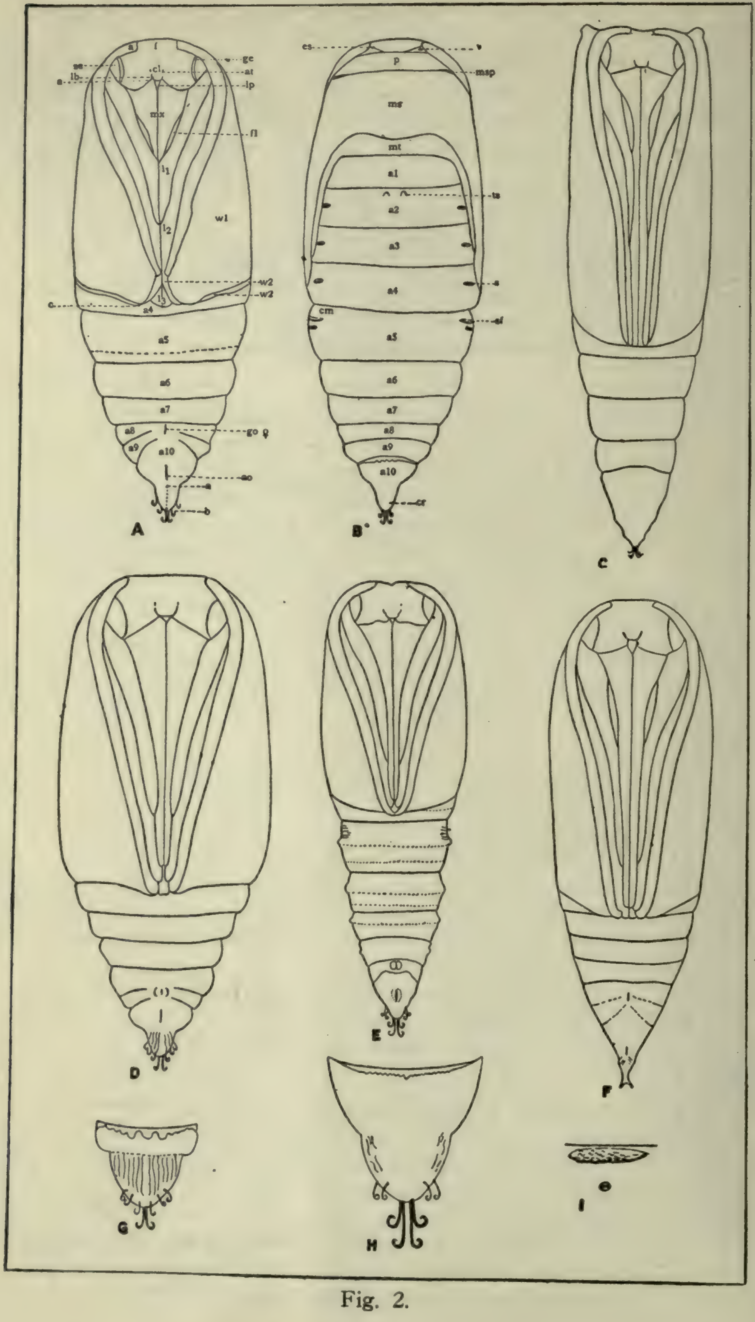
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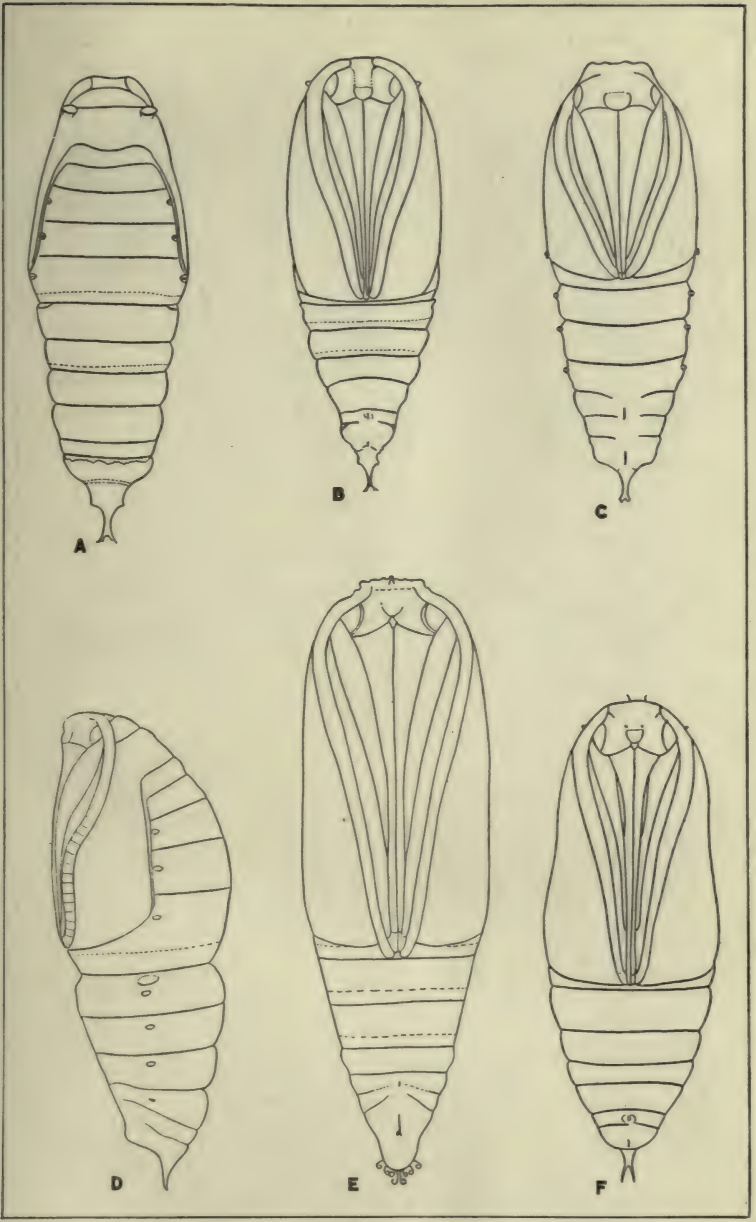
Fig. 2.



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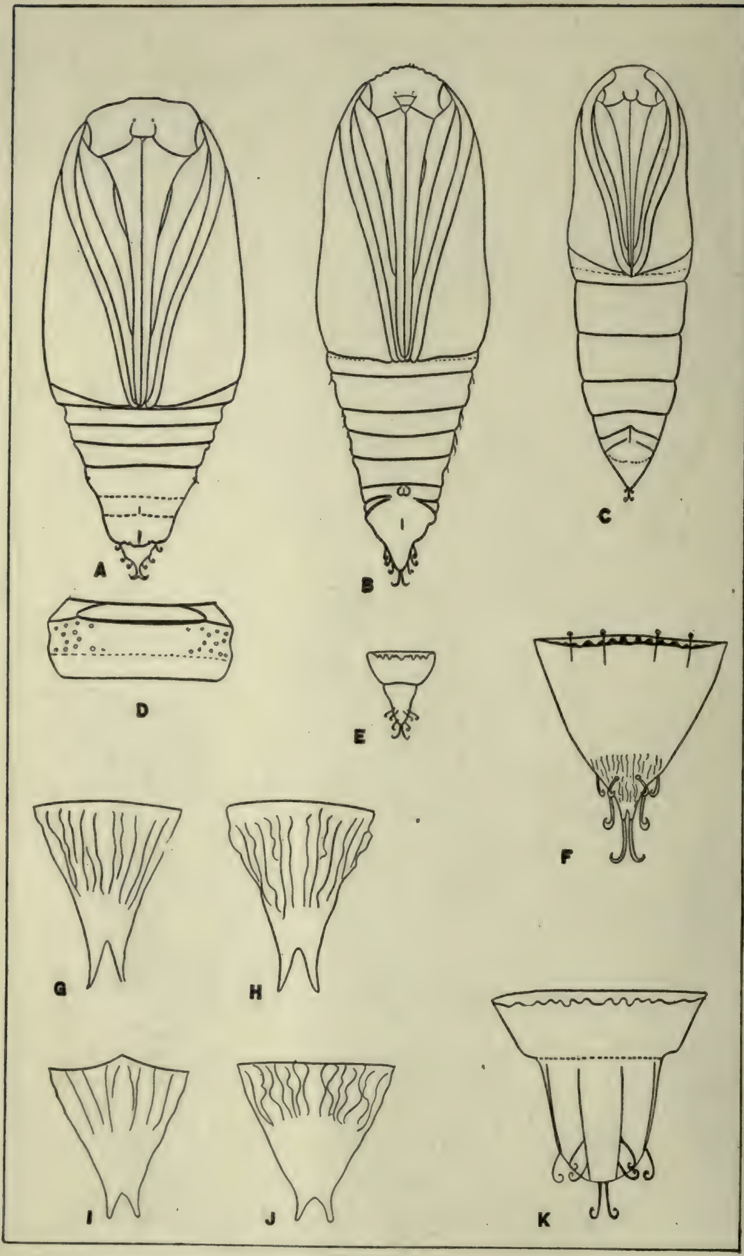

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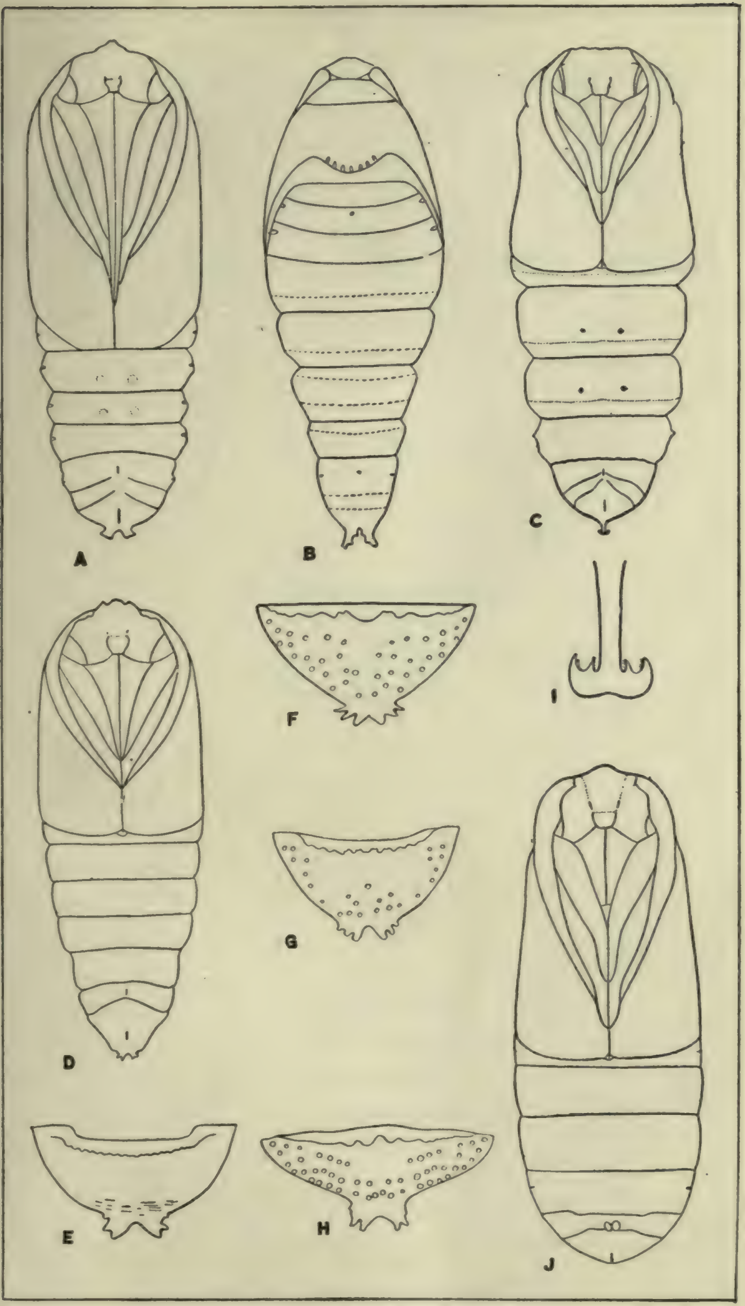

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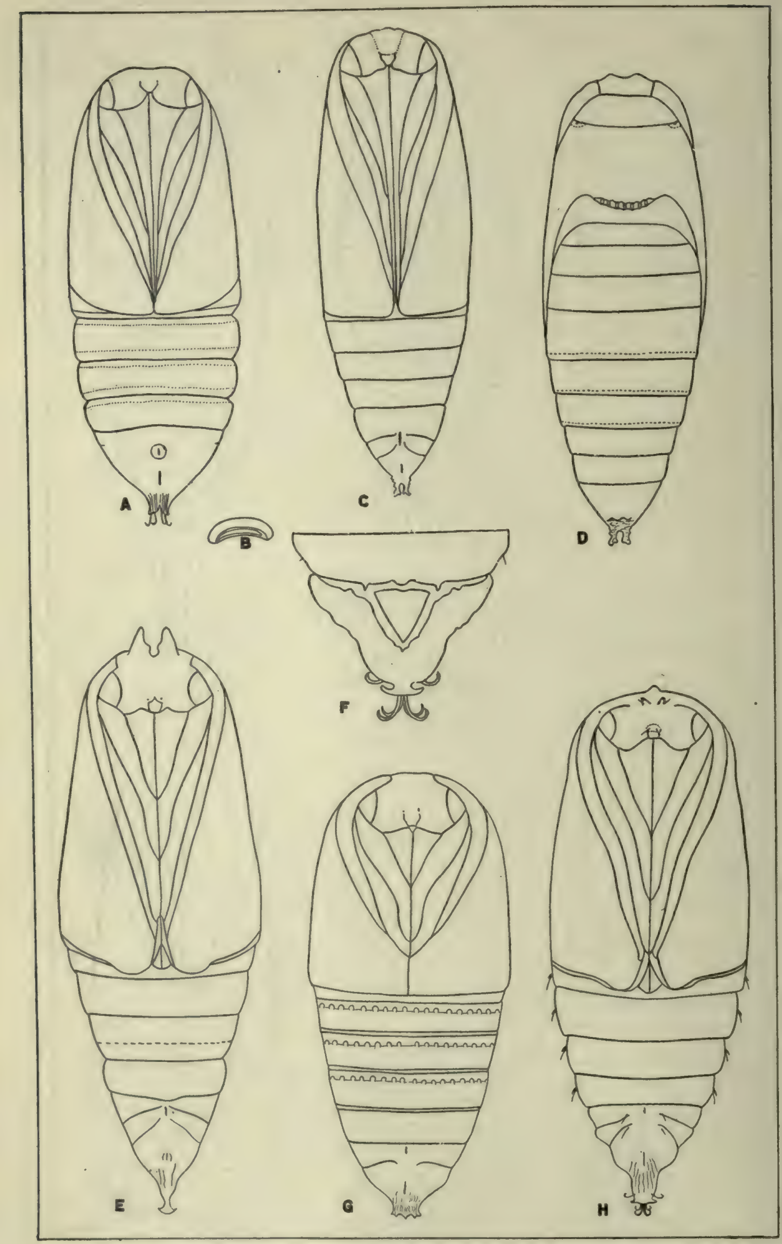

Fig. 6.

APRIL, 1917

BULLETIN 388

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION

THE POPLAR AND WILLOW BORER

ROBERT MATHESON

PROPERTY OF DIVISION OF
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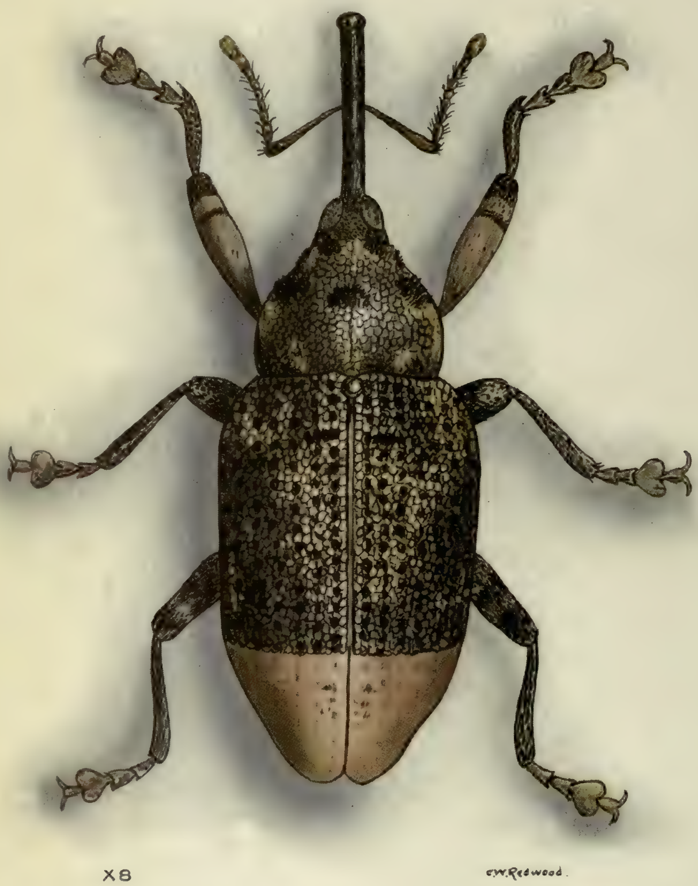

THE POPLAR AND WILLOW BORER
(Cryptorhynchus lapathi)

THE POPLAR AND WILLOW BORER

(*Cryptorhynchus lapathi* Linnæus)

Order, *Coleoptera* Family, *Curculionidæ*

ROBERT MATHESON

Ever since its introduction from Europe, in 1882, the poplar and willow borer or weevil has been a serious pest, not only in nurseries in the eastern part of the United States but also to the basket willow industry and to poplar and willow trees used for landscape planting. During the past ten to twenty years the weevil has become so abundant in many eastern nurseries that in many cases the nurserymen have almost abandoned the raising of carolina and other species of poplars to supply the demand for a rapidly growing shade tree. Also many young groves of poplars have been seriously injured, while large shade trees have been rendered unsightly by the breaking off of branches that have been so riddled by the boring of the larvæ as to be unable to resist high winds.

As this beetle is largely distributed through infested nursery stock, it would seem that the most efficient means of reducing the injury that it causes would be by controlling its work in the nurseries. If nurserymen could furnish trees known to be absolutely free from the pest, its further distribution would be restricted, and means could then be adopted to control its activities where it is at present causing serious injury. During the past three seasons the writer has conducted experiments which have proved very successful in controlling this pest under nursery conditions. These experiments are discussed in the present bulletin, which also gives a biological account of the insect.

HISTORY OF THE SPECIES

In Europe

The poplar, willow, or alder snout beetle, the *Erlenrüssler* of German writers, is a European insect. For centuries it has been a pest to alders and willows in Europe, and it has been the subject of many entomological papers.

Linné (1758) described the adult in his *Systema Naturæ*, giving as its host plant *Rumex lapathi*. Curtis (1791) published the first account of the natural history of the beetle. He found the larvæ injuring ornamental willows in his garden. He first observed the work of the beetle on *Salix viminalis* in 1780, and after a few years of study succeeded in finding all its stages except the egg, which he supposed was laid under the bark or in crevices resulting from injury. His figures of the various stages of the insect are the first ever published. Paykull (1792) records the beetle as injuring Salix species, and also refers to Linné's statement that dock (*Rumex lapathi*) is one of its host plants. Bechstein and Scharfenberg (1804) quote from Curtis's work, and also refer to the injuriousness of the beetle in Germany.

The insect is recorded in all the early systematic works dealing with the snout beetles (Rhynchophora), but no biological data are added. Ratzeburg (1839) records alder as one of its host plants, stating that in Silesia the beetle is known as the alder destroyer (*Erlenwürger*). Nördlinger (1856) records the insect as doing serious damage to young birches from five to eight feet high, their tops breaking off after having been seriously injured by the numerous larval galleries.

Westwood (1863) describes a serious outbreak of the beetle in ornamental willows in Essex County, England. Ratzeburg (1868) gives a much more extended account of the beetle and its injuriousness throughout the forests of Germany. His account of its life history is incomplete, though he gives many details as to its food plants and habits. Altum (1881) records the beetle as doing serious injury to stands of white and of black alder in various parts of Germany, as well as attacking several species of willows. He does not clear up any of the various disputed points not well understood regarding the habits and life history of the insect. Judeich and Nitsche (1889), though they discuss the insect in some detail and list all its known food plants, leave the question of its biology in the same condition as they found it.

The beetle is discussed more or less in detail also in many recent European works on forest and shade tree insects, but no attempt has been made to clear up the many obscure points in its bionomics. Scheidter (1913) gives an extended account of its life history in various parts of Germany, and seems to have added considerable new biological data, much of it differing widely from that found in America.

In America

This European insect was first recorded in America by Juelich (1887), who collected a single beetle at Williamsbridge, New York City, in 1882. In 1887 he found willows infested by the insect at West Bergen, New Jersey. In the previous year Ottomar Dietz had collected a single specimen on Staten Island, so that at this early date the insect was established in the extreme southeastern part of New York and the northeastern corner of New Jersey. Smith (1891) reported its spread in New Jersey and the destruction by it of nearly all the clumps of willows, as well as many fancy ornamental trees, at Newark and Arlington.

Howard (1895) states that E. V. Wilcox sent him specimens of the beetle and the larva from Cambridge, Massachusetts, reporting that willows in that section were severely infested. Jack (1897) records the beetle as being very abundant about Boston and Cambridge, it having been present in the Arnold Arboretum for many years and at that time proving very injurious to many species of willows and poplars and to two species of birches. Up to that time it had been supposed that the insect was restricted to the eastern Atlantic border, but in 1896 Ottomar Reincke collected it near Buffalo.

The beetle has now become well established in the Eastern States but its westward and northward spread has not been very rapid. Burgess (1903) records it from Ashtabula, Ohio, in 1901; Bues (Bues and Sandsten, 1904), from two nurseries in Wisconsin in 1903; and Washburn (1904) reports receiving specimens from the extreme northwestern corner of North Dakota, where the insect had been introduced on nursery stock from New York. This stock had been first shipped to a Minnesota nurseryman, who in turn had distributed it, some of it reaching northwestern North Dakota. It is clear that the beetle was thus, in all probability, widely distributed in the Northwest.

Patch (1908) first observed the insect at Orono, Maine, in 1907, and in 1911 it was found also at Augusta and at Presque Isle. Forbes (1911 a) records the beetle from Chicago in 1908, where it was abundant and destructive throughout the city. He reports that it has not been found elsewhere in the State.

FOOD PLANTS

The poplar and willow borer has a fairly wide range of food plants. European writers record it as attacking the following species: alders — *Alnus viridis* DC., *A. incana* Willd., *A. glutinosa* Willd.; willows — *Salix caprea* L., *S. viminalis* L., *S. purpurea* L., *S. triandra* L.; poplars — *Populus alba* L.; birches — *Betula* species. Jack (1897) states that in America all the native willows except the slender-stemmed species are subject to attack. This is confirmed by C. S. Sargent, Director of the Arnold Arboretum at Cambridge, Massachusetts. Of the imported willows the following have been observed injured in the Arnold Arboretum: *Salix alba* L., *S. fragilis* L., *S. babylonica* Tourn., *S. pentandra* Linn.

The following species of poplars are also recorded as host plants: *Populus balsamifera* L., *P. deltoides* Marsh., *P. alba* L. Schoene (1907 a) records the following species of willows as host plants: *Salix lucida* Muhl., *S. caprea* L., *S. cordata* Muhl., *S. sericea* Marsh., *S. alba* L., *S. amygdaloides* Anders. In addition two species of birch are known to have been injured—*Betula pumila* L. and *B. nigra* L. These, however, are rarely attacked.

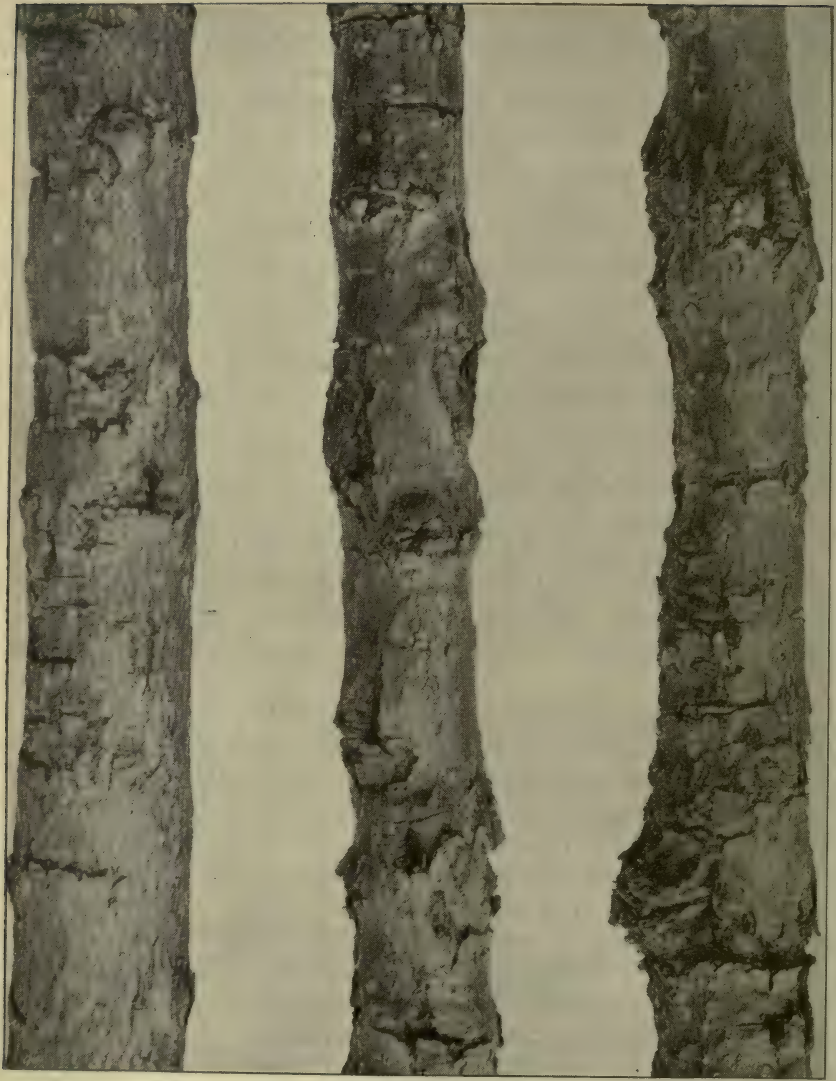

FIG. 111. TRUNKS OF SEVERELY INJURED CAROLINA POPLAR TREES, FIVE YEARS OLD

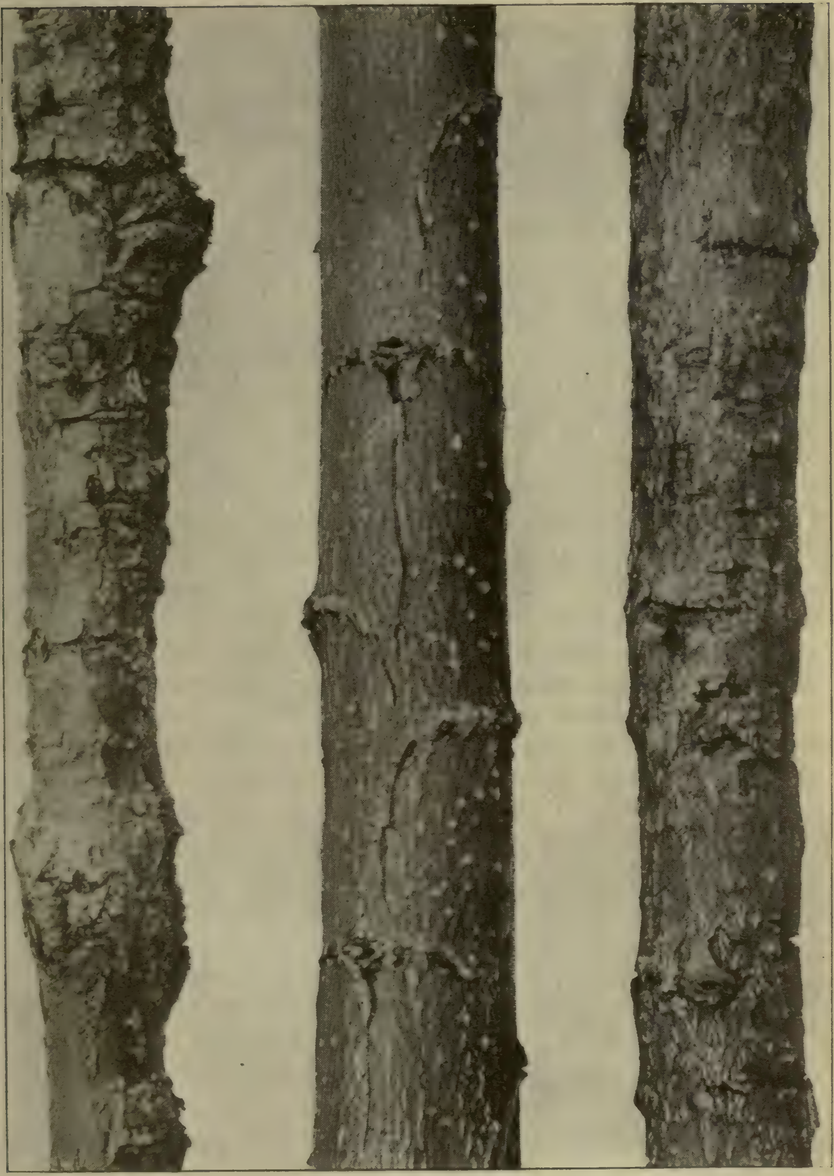

FIG. 112. INJURED AND UNINJURED POPLARS

At right and left, five-year-old trees, severely injured; an uninjured four-year-old tree in the center. All were grown under identical conditions in the experimental plot

ECONOMIC IMPORTANCE

The poplar and willow borer is of greater economic importance than has generally been supposed. It is a serious pest of practically all species of willows, and where the beetle is abundant the damage done is extensive. This is especially true of all varieties of ornamental willows. Also the production of basket willows is greatly reduced and in many cases stopped by the work of this insect. To many species of poplars it is very injurious, especially when the trees are young (figs. 111 and 112). In many nurseries the production of poplar stock has been discontinued owing to the prevalence and injuriousness of the pest.

The willows (Salix species) and the poplars (Populus species) are regarded generally as of not much value. However, many willows are used extensively in landscape work, not only for their quality of rapid growth but also for their beauty. Species native to this country line the streams and encroach on the boundaries of lakes and ponds, serving a very useful purpose as holders of the soil. The carolina poplar, though not looked upon with much favor as a shade tree, has been and is being planted rather extensively in recently developed areas. This is especially true in the Middle West, where the trees soon become suitable for lumber. Extensive plantings made from forty to fifty years ago in the Middle West, and also the great areas of cottonwood in the lower Mississippi Valley, are now being lumbered. The product finds a ready sale as lumber and commands a good price for excelsior. The carolina poplar is used also on sandy areas to keep the soil from being washed away.

The balm-of-Gilead poplar, which is used generally as a shade tree, is severely attacked by the borer. The branches serve excellently for the development of the insect, and in sections where it is prevalent scarcely a sound tree can be found. The branches, weakened by the larval burrows, are broken off by high winds and ice storms, rendering the trees unsightly.

In Europe the beetle has proved a pest to many species of willows, poplars, and alders. Many accounts are given of its destructive work, and there is no doubt that it is proving even a worse pest in America.

DISTRIBUTION

The beetle, recorded as having first appeared in America in 1882 (Juelich, 1887), has not spread very rapidly. It is at present known to occur from Maine west to Ontario and North Dakota and south to the District of Columbia. Throughout this area it is restricted to certain localities, and once introduced it does not spread rapidly unless carried by some agency. It is reported by Fletcher and Gibson (1909) as occurring at Dundurn, Saskatchewan, but nothing is known as to its spread in this province. It has not been found west of the Great Plains.

The preceding statement as to the general distribution of the beetle is based on letters received from various officials regarding the situation in their respective States. P. A. Glenn informs the writer that in Illinois the beetle is abundant about Chicago and occurs generally in the northern fourth of the State, while in the central and southern parts it has not been found. Dr. Fracker reports it as widespread in the nurseries of Wisconsin, where it has been found as far north as the shores of Lake Superior. Blatchley and Leng (1916) state that it has not yet been found in Indiana. Professor R. H. Pettit says that it is common in Michigan and probably occurs wherever the carolina poplar grows. In Ohio it seems not to have spread to any considerable extent since its first appearance there in 1901. It has not yet been found in Nebraska, South Dakota, Iowa, or Indiana.

In Canada, according to Caesar (1916), it is well distributed throughout Ontario and is also recorded from a few localities in the province of Quebec.

LIFE HISTORY

Although this beetle has been a serious pest in Europe for hundreds of years, its life history has never been fully investigated by European workers. Even at present there is the widest divergence between the accounts given by American and by European writers. This is brought out in detail in the discussion of the various activities of the different stages.

The adult

The poplar and willow borer (Plate XXII) belongs to the great group of snout beetles, Rhynchophora, and to the family Curculionidæ. This family contains an immense number of species, many of them very serious pests, including the common plum and quince curculios. The beetle measures from $\frac{1}{3}$ to $\frac{2}{5}$ inch in length, is robust, and is elongate-oval in shape. It is densely clothed with black and pale-colored scales, intermixed with erect, large, black bristles. The pale scales cover the apical third of the elytra and form an irregular band on the basal third; the underside of the prothorax and part of the legs are also densely clothed with them, and the remainder of the body bears a few scattering ones. The beak is curved, is as long as the head and the thorax, and lies when at rest almost completely concealed in a groove on the ventral surface of the thorax. The antennæ are elbowed and reddish brown, with an unsegmented club.

The beetles begin to appear during the latter half of July, becoming abundant in August. The writer found them present on poplar trees as late as October 7. After that date they could not be found on the trees in the writer's experimental plot. They are sluggish, very inactive insects, and move with a slow, lumbering gait. When they are disturbed, either by being jarred or by any sudden noise, they do not fly but feign death and drop to the ground, the beak and the legs being closely drawn against the body. They remain quiescent usually for a minute or two before attempting to crawl away. When handled they emit a squeaking noise, produced by the rubbing together of parts of the body. Though close watch for it has been kept, flight has not been observed, and no one has recorded the beetles as spreading by means of flight. Whether or not they are incapable of flight the writer has not been able to determine.

Shortly after the beetles emerge from the pupal cells they begin to feed, selecting young, tender shoots. The bark is punctured by the beak, a round hole being formed down to the cambium layer, on which the beetles largely feed. The beetles are voracious feeders, and when they are abundant the young one-year-old shoots may be so completely riddled by the feeding punctures that they shrivel and die. So far as the writer's observations go, the beetles do not feed on old bark, but confine themselves to the young and succulent twigs. Punctures in old bark are for the deposition of eggs, and these always appear some weeks after the beetles have been feeding.

The beetles do not seem to migrate to any considerable distance. Although the wings are perfect and apparently suitable for flying, yet the beetles have never been observed in flight or attempting to fly. In the nursery it is not uncommon to find one block badly infested, whereas a block somewhat distant may be only slightly injured. Change of location in the growing of poplars from year to year frequently makes a marked difference in the degree of injury. One block of about 15,000 trees in a large nursery near Geneva had an infestation of nearly 50 per cent in 1915. A block of about the same number of trees situated three-fourths of a mile distant showed in 1916 only a small infestation, 3.5 per cent, in the check rows. The beetles were abundant in 1915 in the block ready to be dug, and apparently they had confined their egg-laying operations to the poplars from which they had emerged. As this is true in all the cases coming under the writer's observation, it can readily be seen that a block ready to be dug, showing only a small percentage of infestation, may make an ideal center for distribution. As the nurseryman discards only severely injured stock, a block with such a low percentage of injury will practically have all the trees fit for sale, and in this way every egg deposited will be shipped away to start new infestations. When trees show considerable injury they are discarded and burned (fig. 113).

Although the beetles do not fly, yet they are undoubtedly well able to walk considerable distances. How far has not been determined, but they have been found a goodly distance from any of their food plants resting quietly on the trunks of various trees. This is especially true in the spring.

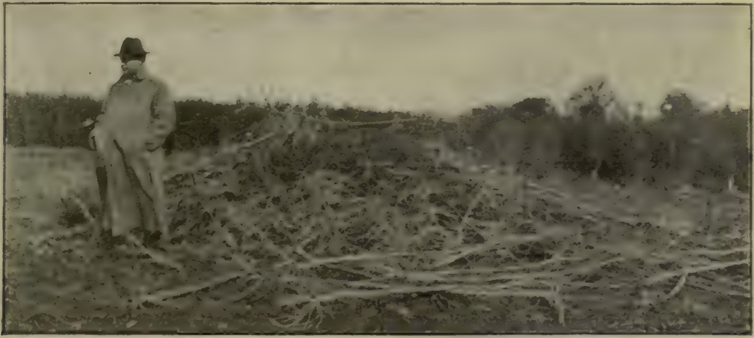

FIG. 113. A PILE OF DISCARDED CAROLINA POPLARS IN A NURSERY

Mating does not occur until ten days or more after emergence. This period is spent largely in feeding, and the beetles do considerable damage at this time to the vigorous growing shoots. Copulation occurs freely and a pair may remain several days in copula. Not only does mating last a considerable time, but it may be repeated again and again at different times.

Egg laying

Shortly after copulation the females seek out suitable places for the deposition of their eggs. They choose branches or parts of the trees more than a year old, and deposit their eggs in the corky parts of the bark. The eggs have never been found in one-year-old stock, but only in wood two years old or older. Favorite places for egg laying are lenticels (figs. 114 and 115), scars, bases of branches, injured areas, or about the base of buds where the bark is somewhat thick. With her beak closely applied to such an area the female beetle at once begins to eat into the bark. Gradually she deepens the round hole until her entire beak is buried, up to the eyes. The time required for this operation varies from a few minutes to thirty or forty minutes. At the bottom of the hole the beetle may round out two or three small lateral cavities, or she may be content with only one. In the majority of

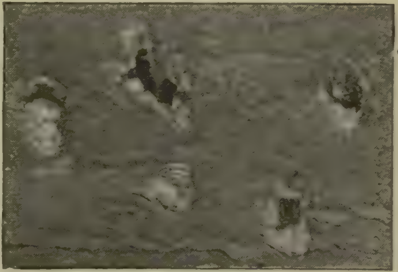

FIG. 114. EGG PUNCTURES AT THE SIDES OF LENTICELS

cases she does not dig out extra cavities, but uses the hole made for the deposition of but a single egg. When the cavity appears satisfactory, the beetle inserts her ovipositor and deposits from one to three or four eggs, depending on the kind of cavity dug. Then, reversing her position, she closely packs the eggs, both with beak and with antennæ, and covers them with fine pieces of the wood.

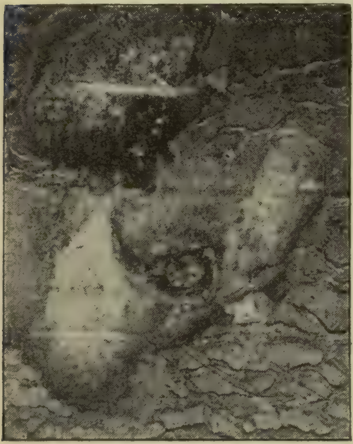
FIG. 115. EGG IN SITU, WITH OUTER PART OF LENTICEL CUT AWAY

Egg laying continues from early August until October, but the number of eggs laid by a single female has not been ascertained. Whether or not, under New York conditions, all the females deposit all their eggs during this period, has not been finally determined. All American workers report that egg laying is finished in the autumn, and that the beetles do not hibernate but evidently die after the process is completed. In the writer's work no hibernating adults were found in the spring in the nurseries, though it should be understood that no extended search was made for them. In the writer's experimental plot, adults which evidently had hibernated were taken on April 21, May 1, and June 6, 1916. One was fresh and clean, apparently having but recently emerged from its pupal chamber. Though these were observed, they may be only rare occurrences rather than represent a normal mode of hibernation. Furthermore, egg laying was not observed in the spring, and in the treated plots there was no evidence that any eggs were laid after application of the various treatments. Had egg laying in the spring been normal, certainly the treated plots would not have shown such a high percentage of control.

The egg

The egg when laid is pure white in color but it becomes pale cream when a few days old. The shell is very thin and fragile, somewhat viscous, and without any distinctive markings. The egg is oval in outline, measuring 1.1 by 0.8 millimeters. The shape varies considerably, since owing to the softness of the shell it is easily modified by the shape of the cavity in which the egg is laid.

The egg stage lasts from eighteen to about twenty-five days, depending largely on weather conditions. The first observation of eggs hatching out of doors was on October 2, 1916. Undoubtedly many had hatched earlier, but from numerous examinations made during October the majority of the eggs had not hatched even as late as October 28. Early in November, 1915, the eggs began hatching in great numbers, and this continued until the latter part of the month.

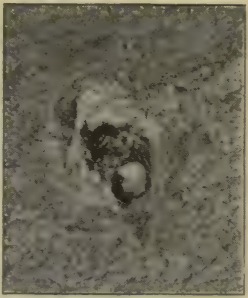
FIG. 116. YOUNG LARVA, JUST HATCHED

The larva

When hatched, the young larva (fig. 116) is whitish in color and greatly resembles a miniature June-beetle grub except that the posterior end is the smaller and the larva is legless. It lies curled up in the egg cavity and begins at once to feed on the soft plant tissues. It is 1.5 millimeters in length, and 0.6 millimeter thick at its widest part. It is regularly transversely wrinkled, but the skin is nearly smooth except for scattering fine hairs. The head and the mouth parts are light brown except the mandibles, which are dark brown with black tips. The larva is cylindrical in shape, gradually tapering toward the posterior extremity.

The larva feeds on the tender tissues of the plant and soon reaches the soft cambium layer. Externally the beginning of feeding can be easily recognized by the blackish, wet frass that fills the outer part of the egg cavity. Feeding continues until cold weather, the early-hatching larvæ attaining a considerable growth.

In the spring feeding begins as soon as the weather has become sufficiently warm, usually the first week in April. Moist frass, black to brownish in color, is forced out of the burrow as the larva feeds ravenously. The direction of the larval channels is nearly always around the trunk or the branch, and the larvæ feed at first exclusively in the bark and the cambium layer. As a result the tree is frequently girdled, especially if several larvæ are at work near the same place (fig. 117). The larval channels vary greatly in shape; some are cylindrical and girdle the tree, others are flat, irregularly shaped chambers, while the majority zigzag in various directions through the cambium layer.

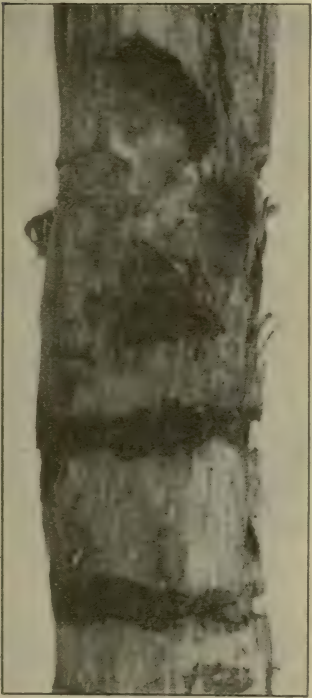
FIG. 117. CHANNELS MADE BY LARVÆ IN A YOUNG CAROLINA POPLAR TREE

As the larvæ grow, the channels become larger and the amount of frass is greatly increased. In order to make room for the developing larva the frass is forced outside the channel, by small openings cut through the outer bark. This is well shown in figure 118.

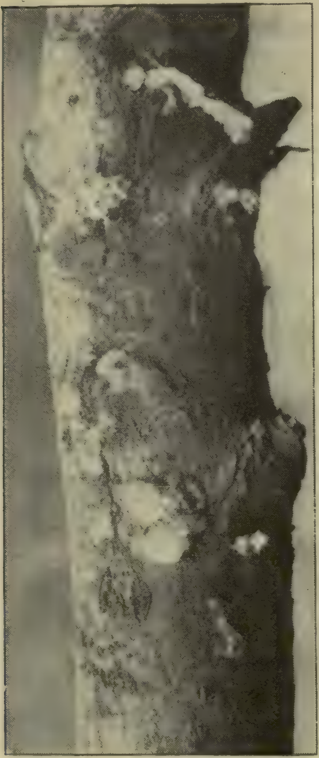

FIG. 118. FRASS FORCED OUT THROUGH SMALL OPENINGS MADE IN THE BARK BY YOUNG LARVÆ

The larvæ become nearly full-grown before they leave the cambium layer. They then burrow at an angle upward into the hard wood of the tree. The beginning of this burrow is easily recognized, as the character and quantity of the frass suddenly changes. It becomes white and much larger in quantity, and consists of small particles of the wood cut off by the mandibles of the larvæ (fig. 119). In New York the formation of the pupal channel begins about June 1. By the middle of June the majority of the larvæ have begun their pupal burrows. At this time, as one looks down the rows of poplars in the nursery the white, sawdust-like frass can be seen distinctly on the infested trees and on the ground beneath them.

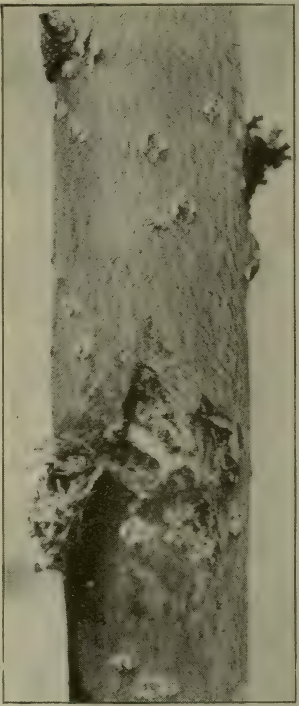

FIG. 119. CHARACTER OF THE FRASS WHEN LARVA BEGINS TO BORE INTO HEARTWOOD TO FORM PUPAL CHAMBER

In the formation of the pupal chamber the larva bores upward and into the heart of the small nursery trees. This burrow varies from slightly over an inch to several inches in length. From three to four weeks are required for its completion. When ready for pupation the burrow is solidly packed with frass, the pupal chamber being formed at the upper end (figs. 120 and 121). The larva then places itself head downward in preparation for pupation.

The mature larva (fig. 122) is a thick, legless grub, resembling that of the June beetle. It measures from 12 to 13 millimeters in length, with a maximum width of 4 millimeters. It is white or yellowish white in color, with a reddish brown head. The heavily chitinized mouth parts are black. There are no outstanding markings that distinguish this grub from many other wood-boring larvæ, and the surest way of identification is by its habits.

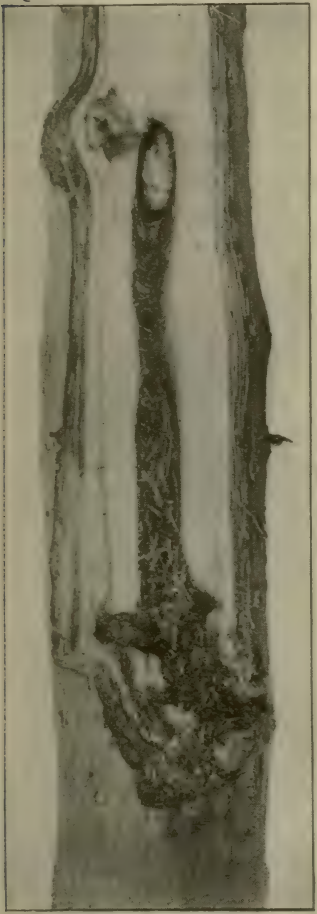

FIG. 120. PUPA IN SITU

The pupa

Pupation begins in the last few days of June and continues throughout July. The pupal period varies from ten to eighteen days, depending largely on weather conditions. Pupæ formed early in July require only ten days, while those of late July require as long as eighteen days, to transform into adults. From two to three days are required for the adult to become fully colored and hardened. Those maturing early in the season usually remain in the pupal cells for two or three weeks before emerging. A general emergence of the adults occurs during the latter part of July. The beetle, when ready to leave, simply cuts its way out through the frass that had been packed in the burrow by the larva before pupation.

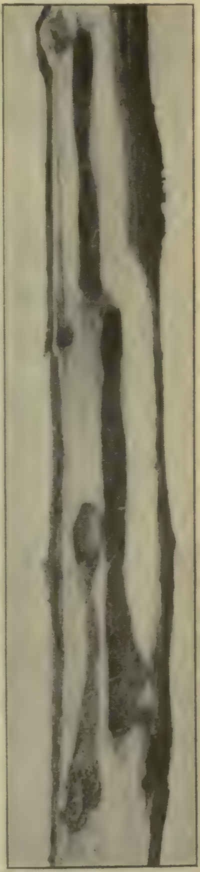

FIG. 121. THREE PUPAL CHAMBERS FORMED IN A TWO-YEAR-OLD CAROLINA POPLAR

The pupa (fig. 123) measures 9 millimeters in length. It varies from almost white to yellowish in color, the brown spiracles showing distinctly. Scattered over the dorsal surface are many small spines. Some of them stand out prominently on the pronotum. The tip of the abdomen is armed with a pair of strong, incurving, brown, chitinized hooks.

Observations of European workers

The life history of the insect as outlined in the preceding paragraphs differs very markedly from that given by European workers, all of whom record the beetles as hibernating and state that mating and oviposition takes place during the spring months.

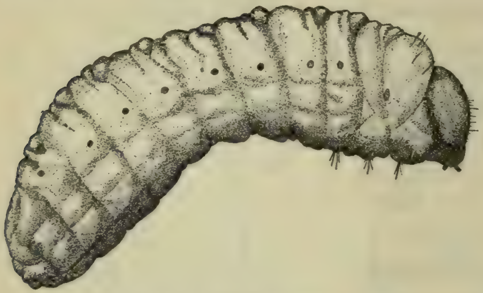

FIG. 122. THE MATURE LARVA

The latest worker, Scheidter (1913), states that the beetles emerge from hibernation about the first of May, and that in a short time mating takes place and egg laying continues throughout the summer. According to his observations, these eggs do not hatch until the following spring, so that each year both eggs and beetles of different generations hibernate. He concludes that with this insect there is a complete generation every two years: beetles emerging in 1910 hibernated, and laid eggs in 1911; these eggs hibernated, and hatched in the spring of 1912, the beetles reaching maturity in late July and August; these beetles in their turn mated and oviposited in the following spring.

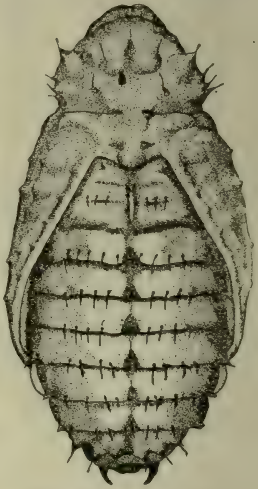

FIG. 123. THE PUPA

Munro (1914) finds that in northern Scotland there is a complete generation every year, the beetles hibernating and ovipositing during the spring months.

Caesar (1916) finds that in Ontario considerable numbers of the beetles appear in the early spring months, but he does not know whether these have hibernated as beetles or as larvæ or pupæ. He also failed to determine whether they lay eggs during the spring months.

It would thus seem that the life history and habits of this insect are complex and vary greatly.

CONTROL MEASURES

When the writer began work on the poplar and willow borer, no efficient control measures had been devised. The general recommendations had been the cutting-out and destruction of infested trees. Schoene (1907 a) states that the use of arsenicals during July and August will kill the majority of the beetles and reduce infestation in nurseries. In practice it has been found that paris green and lead arsenate, even when used in large quantities, have no effect in reducing the annual loss. At the time when the writer began to look into this problem, in 1913, several large nurseries in New York State had about decided to stop raising carolina poplars, although there was a steady demand for this stock.

Early observations led the writer to the conclusion that the insect could be destroyed by some contact spray applied to the trunks of the trees in autumn, after the leaves had fallen, or in spring before the young larvæ had begun actively feeding. This seemed very reasonable, owing to the fairly exposed condition of the young larvæ in their burrows. It seemed that some oil emulsions would penetrate the outer bark or be absorbed through the very small quantity of frass at the entrance to the burrows, and would destroy the insects. Consequently, varying strengths of miscible oils and kerosene emulsion, applied both in the fall and in the spring, were experimented with. In order to secure a strong penetrating fluid, it was felt that carbolineum avenarius should be given a thorough trial. Very little is known about the constituents of this preparation, and furthermore very little is known of its effects on actively growing or on dormant trees.

FIG. 124. AN EXPERIMENTAL PLOT OF CAROLINA POPLARS

Experiments in 1913–14

In the fall of 1913, seventy-six badly infested two-year-old poplar trees were planted near the insectary at Cornell University (fig. 124). On December 1, 1913, a part of this block was treated with scalecide at varying strengths, and a few trees were treated with carbolineum and its emulsion,[1] as indicated in table 1. This experiment was closely watched the following spring, but no injury to the trees could be noted except that the carbolineum-treated trees did not seem so vigorous as the others. However, they grew, and in 1916 they were large, healthy trees. Examination and careful count of the burrows in all the trees was made on June 17, 1914. The infestation is shown in table 1:

TABLE 1. RESULTS OF EXPERIMENTS OF 1913–14

Treatment	When applied	Number of trees treated	Date of examination	Number of trees infested	Average number of larvæ per tree	Number of trees not infested	Per cent of trees infested
Scalecide 1–5*	December 1, 1913	10	June 17, 1914	3	2.6	7	30
Scalecide 1–8	December 1, 1913	10	June 17, 1914	4	1.25	6	40
Scalecide 1–10	December 1, 1913	10	June 17, 1914	7	2.3	3	70
Scalecide 1–12	December 1, 1913	10	June 17, 1914	8	1.9	2	80
Scalecide 1–15	December 1, 1913	10	June 17, 1914	5	2	5	50
Carbolineum 1–1	December 1, 1913	2	June 17, 1914	0	......	2	0
Carbolineum emulsion 1–2	December 1, 1913	2	June 17, 1914	0	......	2	0
Check	....	22	June 17, 1914	10	2.6	12	45

* All dilutions of scalecide are with water.

In the spring of 1914 a series of experiments was undertaken in a large nursery. Stock three years old was chosen, as it was the most readily available at the time. Badly infested trees were selected at one side of a large block which had been recently dug. Directly across the roadway was a block of young poplars. On March 31, scalecide at varying strengths, carbolineum, and carbolineum emulsion were applied to the trunks from the ground up to the young growth. The day was fair, but rain began to fall before the various treatments were completed. However, the rainfall was slight, so that it should have had no effect on the insecticidal qualities of the preparations.

The treated trees were examined carefully on May 14, 1914. The various treatments had no effect on the growth of the trees, every tree growing vigorously and there being no difference, as far as could be detected, between the checks and the trees under experimentation. In the checks the larvæ were actively at work and their abundance was indicated by the amount of sawdust exuding from the numerous burrows. All the trees treated with different strengths of scalecide showed just as high a percentage of infestation as did the checks. This preparation had no appreciable effect. In the trees treated with carbolineum, either pure or as an emulsion, not a trace of infestation could be found. After a search of several hours, one shriveled and blackened larva was discovered in its burrow. It was not desirable, however, to injure the trees too much by cutting into all suspicious egg punctures.

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[1] The carbolineum emulsion was prepared by dissolving 1 pound of sodium carbonate in 1 quart of hot water, adding 1 quart of carbolineum, and stirring the mixture vigorously.

The trees were again carefully examined on June 18, when the previous observations were confirmed. The checks and the trees treated with scalecide were nearly all badly infested, many trees having from eight to ten borers present, while a few, both of the treated trees and the checks, were apparently free from infestation. The trees treated with carbolineum and its emulsion were growing even more vigorously than were the untreated trees, and not a trace of the work of the borer in any one of the twelve treated trees could be discovered. These preparations colored the trunks of the trees deep brown, but other than that no injury could be seen.

Experiments in 1914–15

In view of the possibility that such perfect control might be due to other causes than the effect of the treatment, a larger series of experiments was planned for the fall of 1914 and the spring of 1915. The miscible oils were discarded, and kerosene emulsion, which had been recommended for the control of the locust borer (*Cyllene robiniæ*), was given a trial. In a block of over ten thousand trees, ready for digging in the fall of 1915, rows were selected at the end showing the greatest amount of the feeding work of the beetles. On December 4, 1914, groups of twenty trees each were treated respectively with pure kerosene emulsion, carbolineum emulsion, and carbolineum. Rows for checks were left between the treated rows. The material was applied directly to the trunks, up to the younger growth. On April 9, 1915, twenty-five trees were treated with pure kerosene emulsion, fifty with carbolineum emulsion, and twenty-eight with pure carbolineum. Just previous to these treatments the trees in the whole block had been pruned carefully. The material was carefully brushed over the trunks, covering all the cut surfaces of the recently removed branches.

The trees were examined on June 28. The block as a whole showed severe infestation, sawdust being present at the base of a great many trees, and this could be seen for a long distance down the nursery row. In the rows treated with carbolineum or its emulsion no sawdust could be seen and the trees were growing vigorously, the trunks showing a deep brown color but no indication of borer work (fig. 125). The kerosene emulsion had no appreciable effect, nor did it injure the trees though it was applied in large quantities.

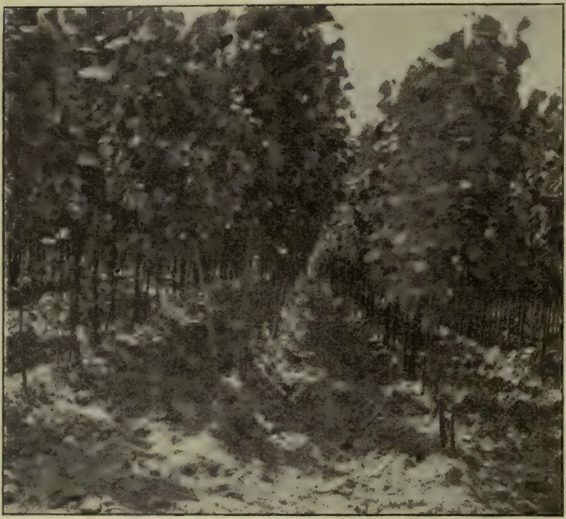

FIG. 125. TREES TREATED WITH CARBOLINEUM AND ITS EMULSION, SHOWING DARKENED TRUNKS. CHECK ROW IN CENTER

The treatments applied and the results obtained are shown in table 2. Kerosene emulsion applied pure in December seems to have had some effect, but one cannot safely draw conclusions from the result shown. The infestation of 30 per cent is high, though the average number of larvæ per tree is at a minimum. The carbolineum applied either pure or in emulsion gave almost absolute control. This seems to the writer to be a very simple and effective means of control under nursery conditions.

TABLE 2. RESULTS OF EXPERIMENTS OF 1914–15

Treatment	When applied	Number of trees treated	Date of examination	Number of trees infested	Average number of larvæ per tree	Number of trees not infested	Per cent of trees infested
Kerosene emulsion, pure	December 4, 1914	20	June 28, 1915	6	1	14	30
Kerosene emulsion, pure	April 9, 1915	25	June 28, 1915	16	2.25	9	64
Carbolineum emulsion	December 4, 1914	20	June 28, 1915	0	......	20	0
Carbolineum emulsion	April 9, 1915	50	June 28, 1915	0	......	50	*0
Carbolineum	December 4, 1914	20	June 28, 1915	0	......	20	0
Carbolineum	April 9, 1915	28	June 28, 1915	0	......	28	0
Check	....	116	June 28, 1915	56	2.4	60	48

* One half-grown larva was found in July, in an area evidently not thoroughly treated.

Experiments in 1915–16

The success of the preliminary experiments led to the trial of the carbolineum treatment on a commercial scale. In the fall of 1915 arrangements were made to treat two entire blocks of poplar trees in each of two large nurseries. This was made possible by the courtesy of the owners, who provided all the material, help, and necessary equipment, the writer taking charge of the work. Each block contained approximately fourteen thousand trees. Owing to the excessive snowfall during the winter of 1915–16 it was not possible to apply the carbolineum as early as was intended. The application was further delayed somewhat in order that the trees should be pruned.

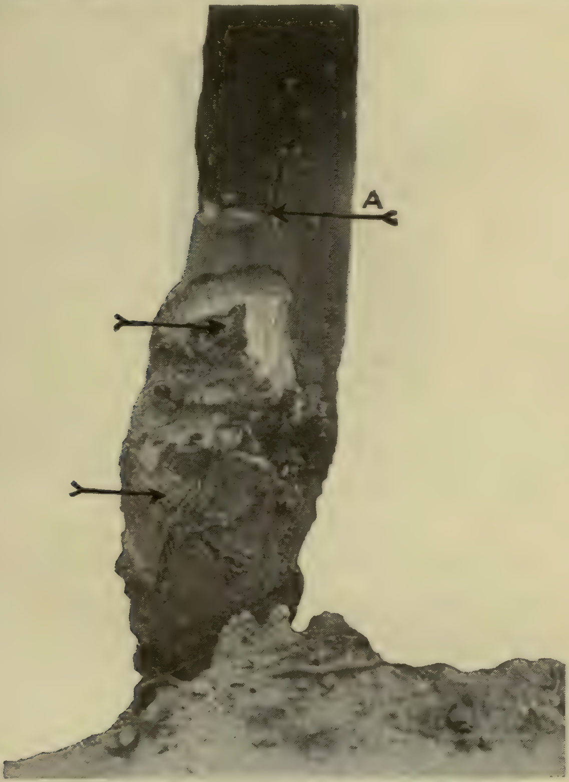

FIG. 126. INFESTATIONS BELOW LINE OF CARBOLINEUM TREATMENT

End of treatment shown by arrow A

On April 8, 1916, twenty-one rows in one block were treated. As the day was cold, threatening snow and sleet, the work was discontinued. During the following day over three inches of snow fell, and the remainder of the block was not treated until April 13. In the meantime the borers had begun feeding; in fact they had been active since about the early days of April. The results of the treatments in this block are shown in table 3.

It is seen from table 3 that practically absolute control was obtained with the carbolineum treatment. Unfortunately for the experiment, the entire check row did not show a high percentage of infestation, but it is sufficient to indicate that the treatment was effective.

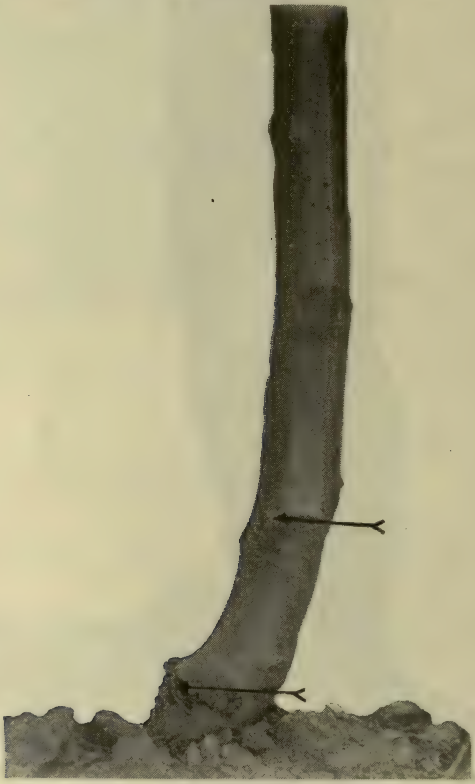

FIG. 127. TWO INFESTATIONS ALONG EDGE OF TREATMENT

In addition to the carbolineum, a high-grade creosote was tried in a limited way. The creosote also gave perfect control, and this promises well, for the row treated stood directly next to the check row.

The carbolineum gave the bark of the trees a deep brown color but it in no way affected their vigor. This brownish coloration gradually becomes reduced during the summer, but treated trees can be recognized easily at least three years after the treatment.

Another point that should be brought out here is that the four trees treated with carbolineum in the experimental plot in 1913–14 were not attacked during the summers of 1914 and 1915, and only a single larva was found in them during 1916. This would indicate that carbolineum-treated trees are not readily selected by the females for oviposition, provided untreated trees are available. This point will be further investigated by the writer.

TABLE 3. RESULTS OF EXPERIMENTS OF 1915–16

Treatment	When applied	Number of trees treated	Date of examination	Number of trees infested	Average number of larvæ per tree	Number of trees not infested	Per cent of trees infested
Carbolineum..........	April 8, 1916	5,000 ±	June 22, 1916	0	0	*1,161	0
	April 13, 1916	9,000 ±	July 20, 1916	*1	1	1,160	0
Creosote..............	April 8, 1916	136	June 22, 1916	0	0	136	0
			July 20, 1916	0	0	136	0
Check................	....	313	June 22, 1916	9	2	304	2.9
			July 20, 1916	11	2	302	3.5

* In determining the infestation of the treated trees, not all the 14,000 trees were examined. Rows were selected in different parts of the block and every tree was examined carefully. In this way 1161 trees were closely scrutinized and not a sign of borer work could be found. The figures in the table are based on the result of this examination. In the second examination a single larva was found at work on one of the treated trees, but as this was the rare exception the fact has been ignored in the percentage column.

TABLE 4. RESULTS OF EXPERIMENTS OF 1915–16

Treatment	When applied	Number of trees treated	Date of examination	Number of trees infested	Average number of larvæ per tree	Number of trees not infested	Per cent of trees infested
Carbolineum...	April 12 and 13, 1916	14,000	June 23, 1916	20	1.4	*1,540	1.28
			July 20, 1916	20	1.4	*1,540	1.28
Check..........	....	84	June 23, 1916	8	1	76	9.52
			July 20, 1916	8	1	76	9.52
Check (treated in June)........	....	555	June 23, 1916	19	1.2	536	3.42
			July 20, 1916	19	1.2	536	3.42

* Only 1560 trees were examined, but these were selected rows and the percentage of infestation is fairly accurate.

The results of the treatment of the second block of about an equal number of trees are shown in table 4. In this block the results were extremely interesting, showing most conclusively the effectiveness of the carbolineum treatment. The writer visited this nursery and showed the owner the method of treatment but did not further supervise the work. In treating the trees on the following day the workmen failed in many cases to cover the base of the trees with the material, and also failed to apply it sufficiently high on the trunk. As a result all the infestations, amounting to nearly 1.3 per cent, occurred either at the base or above the highest point of treatment. This is well shown in figures 126, 127, and 128.

Another interesting point in connection with this block is in regard to the check row. This row, running through the center of the block, contained 639 trees. When the owner saw the excellent results in the treated trees, he asked himself why he should not save most of the trees in the check row. Therefore on June 3, 4, or 5 — he did not know the exact date — he treated 555 of these trees, leaving some at either end as a true check. The treatment, even at this late date, had a marked effect, as shown by the percentage of infestation found on June 23. During the first week in June all the larvæ were still at work in the cambium layer, and wherever sufficient material was applied most of the larvæ were killed. The trees then readily outgrew the injury. The carbolineum had no apparent effect in retarding growth.

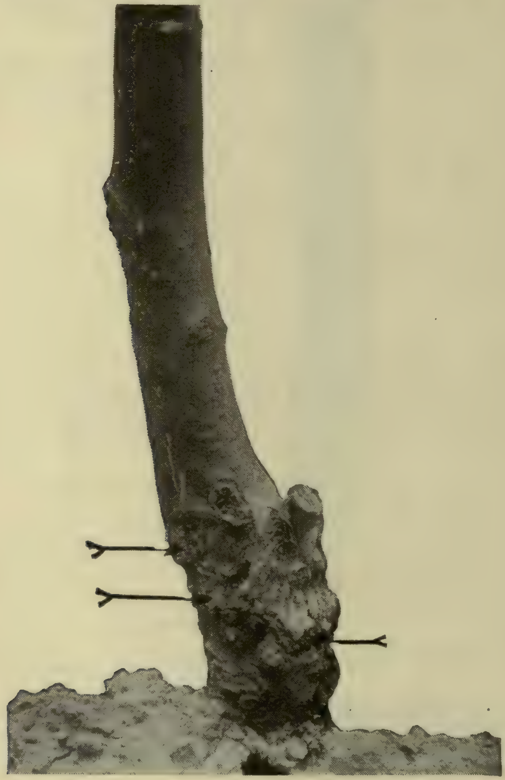

FIG. 128. TREE SEVERELY INJURED AT BASE, DUE TO LACK OF TREATMENT THERE

Method of application of carbolineum

After many trials it was found that the simplest method of application of carbolineum was by the use of cotton waste. Carbolineum is non-injurious to the hands, and each workman carried a small quantity of the material in a dipper or a tin can. The cotton waste was dipped into the material and then rubbed carefully up and down the trunk of the tree. It is usually not necessary to go higher than four or five feet, but great care should be exercised to see that the base of the tree is well treated and all parts of the trunk are well covered. At the same time the material should not be allowed to run down to the roots. After the trees are pruned workmen can apply the material at a very rapid rate.

It is preferable to make the application on a warm day, as under this condition the carbolineum is thinner and may be more easily applied.

Cost of treatment

It was at first thought that the cost of the treatment might prevent its use under nursery conditions, inasmuch as poplars are not very high-priced stock. In one nursery a careful account of the entire cost of treatment was kept. This was as follows:

Labor, treating 14,000 trees	$18.50
Carbolineum, 7 gallons at 90 cents	6.30
Total cost	$24.80
Total cost per tree	$0.00177

It is thus seen that the cost per tree is extremely small, not exceeding two-tenths of a cent — a practically negligible charge.

SUMMARY

The poplar and willow borer is a European pest recently introduced into America and at present widely distributed in the northeastern United States. It is proving a serious pest not only in nurseries but also wherever willows or poplars are grown.

A very effective means for control of the insect is the use of carbolineum avenarius. In nurseries this should be applied by hand during the latter part of March or the first week in April. The work can be done most advantageously just after the trees are pruned.

In setting out poplar trees they should be treated with carbolineum in order to insure the destruction of all larvæ present. This can be done either in the fall or in the spring while the trees are dormant.

The item of cost has been shown to be extremely small, not exceeding two-tenths of a cent per tree under nursery conditions.

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STILLWATER, OKLAHOMA

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THE SYCAMORE LACE-BUG

(*Corythucha ciliata,* Say)

BY OTIS WADE

DEPARTMENT OF ENTOMOLOGY

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THE SYCAMORE LACE-BUG

(*Corythucha ciliata,* Say)

INTRODUCTORY

The importance of the sycamore lace-bug as a pest in Oklahoma first occupied the writers' attention two years ago (1915) while making a study of the western sycamore or buttonwood tree (*Platanus occidentalis*) as a suitable shade tree.

Previous to the summer of 1915, when this problem was first taken up by the writer under the direction of Professor Sanborn, considerable data and material relative to the life history and habits of this insect had been worked out by the Station entomologist, but this data, together with Ms., collections, etc, was entirely lost in the Morrill Hall fire. This necessitated beginning anew the entire project, which the writer was fortunate in being allowed to undertake.

Since this tree is gradually coming into favor for planting throughout its natural habitat the seriousness of this insect's attacks caused a thorough study to be made of its life history and habits, and of the most practical methods for its control.

The western sycamore has few serious insect enemies and, in Oklahoma, is practically free from insect depredations, aside from the bag-worm and this lace-bug, which is found wherever its host tree thrives.

HISTORICAL

The family *Tingidae,* to which the sycamore lace-bug belongs, presents a very interesting group of unique and beautiful insects which have scarcely received the attention they deserve from economic entomologists until quite recently. Some of the more important ones which have been studied in detail are the Oak Tingid (*Corythucha arcuata,* Say) by Morrill, and *Gargaphia solani,* Heid, by Fink. The latter species is quite important as a pest of the eggplant.

The lace-bug of the sycamore was described by Say in 1831 as *Tingis ciliata.* In 1873 Stal created the genus *Corythucha* and transferred *ciliata* to it.

DISTRIBUTION

The sycamore lace-bug is widely distributed throughout the United States; it is the most common and probably the best known of the *Tingids*. The writer has found it in every locality in Oklahoma where the sycamore is grown. During the summers of 1915 and 1916 it was particularly abundant in Oklahoma City, Muskogee, Tulsa, Guthrie and numerous other localities where the sycamore is becoming more popular, and it was a source of great damage to the foliage, especially of the younger trees.

LIFE HISTORY AND HABITS

C. ciliata is distinctly a sycamore lace-bug and confines itself to the genus *Platanus* so far as I have been able to learn from personal observation and from data of the more recent writers who have been careful to distinguish it from closely allied species inhabiting other host plants.

It is found throughout the range of the western sycamore (*P. occidentalis*) and has been taken into new localities with its host where the tree is grown for street and park shade. Although I made frequent observations in the nurseries of Oklahoma where the eastern plane tree (*P. orientalis*) is propagated, I have never seen it attacking this tree, and I can find no reference in literature to its having been taken from this host. Two other very similar buttonwood trees are found growing wild in the Western and Southwestern United States where the sycamore lace-bug is found and they no doubt act as exclusive hosts. These are *Platanus wrightii* of Arizona and New Mexico and *Platanus race-*

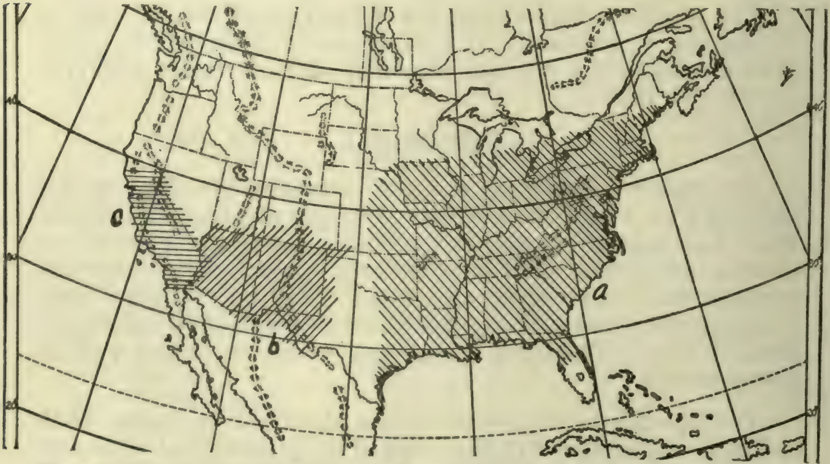

Figure 1—Map showing distribution of *P. occidentalis* in the Eastern United Statse; *P. wrightii* in Arizona and New Mexico; *P. racemosa* in California

mosa of California. The range of these two species is not altogether definite and may extend beyond or overlap the limits shown in the accompanying map.

The under surface of the leaves serve exclusively as feeding grounds and breeding places for the lace-bug, and while the adult is capable of making short flights it stays rather close to the leaves in its immediate vicinity, seldom leaving the tree unless there are other trees adjoining very closely. They seem to pair off, with a male and female found together on a leaf, although several pairs, as many as three or four, may be seen on one leaf. They are never found feeding on the upper surface of the leaves and will not stay if placed there. No doubt they find the surface underneath more easy to pierce and more succulent, together with the protection of the large ribs and downy pubescence of the under surface which attracts them. The immature bug moving about on the leaf with a mass of this fuzz or pubescence attached to the spines of its back, presents a striking and grotesque appearance. The adults, as well as the young, are capable of doing severe injury to the foliage by sucking the sap and leaving the foliage in a whitish, deadened state. The nymphs (immature forms) upon hatching, stay in groups and move about over the leaf, keeping very close together. They seldom leave the leaf upon which they hatch until the fourth stage is reached, when they begin moving about more freely and are inclined to separate into smaller groups or go about singly.

Hibernation

The sycamore lace-bug, as is common with all members of the *Tingid* family, the writer has observed, hibernates in the adult form, usually under the loose, rougher bark of the host tree, or it may sometimes be found in the cracks and crevices of fences, buildings, etc., near or under the sycamore tree. In Central Ohio they may be found going into their winter quarters about the middle of October; in Oklahoma the time is somewhat later, about a month. While there are still immature forms on the leaves in all stages, some of these successfully arrive at the adult stage and go into hibernation, but the majority are cut off with the first real cold and frost before they mature. No immature forms succeed in passing the winter, and seem never to seek a place of shelter in the late fall. The adults are able to withstand pretty severe cold, being able to weather a temperature as low as 10° below zero, although many of them, not favorably protected, succumb to the rigors of winter. In a particularly severe winter, as was experienced in Ohio the past year (1916-17), 50% or less are able to survive till warm weather. The writer collected some 300 individuals on the 15th of October, 1916, put them in salve boxes and placed them outdoors in a well protected place under an old crock.

They were brought into the insectary the 1st of March and less than half of them revived and lived. An interesting fact was here discovered; within fifteen to thirty minutes after being brought in from the cold to a temperature of 60° F., or above, the hibernating forms would be thoroughly active, and when placed on the leaves of the host tree would go to the under side at once and begin feeding. Owing to the milder winters in Oklahoma, a greater percentage are enabled to live till spring in well protected places and, together with the longer season of warm weather, they can accomplish very much more destruction than farther north and east, where the growing season is short.

The hibernating forms, with the approach of warm weather, will come out especially on bright, sunshiny days and swarm about over the trees, but on a cold day they again seek cover. By the time the trees are well in leaf they have ascended to the foliage and are feeding. About ten days are spent in feeding and mating before the females begin ovipositing.

Egg Laying

The eggs are laid along the larger ribs, the female seeming to prefer the forks of the ribs where she thrusts the egg, gluing it to the leaf surface and leaving it partially covered by the leaf fuzz. The eggs may be laid singly or in groups of as many as ten. Less frequently the eggs are deposited in larger, irregular patches on the leaf away from the ribs. Each egg is placed on end, usually erect, but frequently inclined to one side. The act of depositing an egg requires about two minutes, during which time the female has the ovipositor thrust forward against the leaf tissue, the wings are slightly spread and braced against the leaf as she leans back on them, they forming as it were, with the body and legs, a tripod for support while she places the egg and covers it with the sticky secretion. This gluey substance is spread over the chorion and in some instances is so profuse as to partially bury the egg. The females frequently seem to have an overabundance secreted which they exude in small drops when not depositing eggs.

The number of eggs a female will lay has not been determined definitely. The experiments I began in the insectary in early March this year have not had sufficient time to determine this point, as there are still several females ovipositing. One female began depositing eggs on March 18 and had laid a total of 157 eggs when lost in transfer to fresh leaves. Another began depositing eggs March 18 and had laid 284 eggs up to June 9, when she died after being transferred a distance of several hundred miles. An interesting fact was noted in connection with the number of eggs an individual female will lay. The total number for one female for one day rarely exceeds fifteen, usually from seven to ten, and every other day this number is reduced by about half.

To illustrate: The following indicates the number of eggs laid by a female during a period of several days—March 19, 6 eggs; March 20, 12 eggs; March 21, 4 eggs; March 22, 9 eggs; March 23, 2 eggs; March 24, 11 eggs; March 25, 4 eggs. Some intervening days no eggs will be laid at all.

Flight of the Adults

The mature insect, when disturbed, will make short flights, darting about in a zig-zag manner. The flying wings are delicate, membranous structures, not strong enough for flights of great duration. The wing covers are extended at right angles and vibrated rapidly; they serve as balances for the insect while it is flying.

Life Cycle

The breeding experiments conducted by the writer were carried on in the insectary during March and April before the sycamores outside had put forth leaves, and while not exactly representing natural conditions, they should approximate quite closely the average growing conditions in Oklahoma throughout the summer. (See accompanying figure with curve showing the mean temperature and humidity for this period.)

It was found that temperature was an important factor in the time required for the hatching of the egg as well as the time necessary for each nymphal stage. The eggs hatch in from fourteen to twenty-one days. Under optimum conditions they

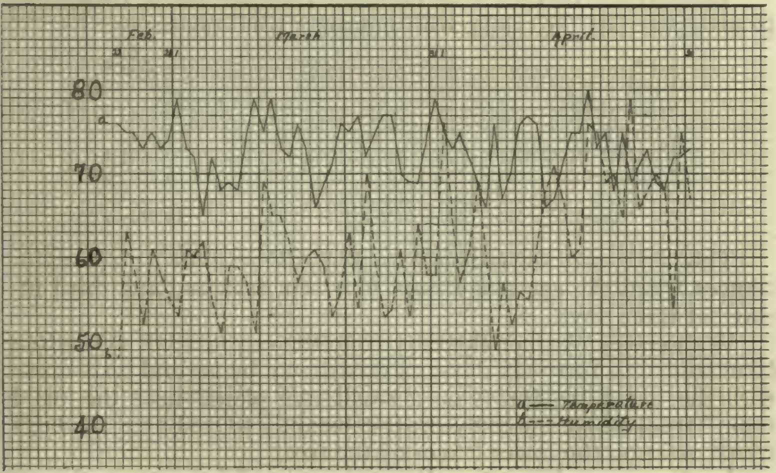

Figure 2—Curve showing humidity and temperature maintained in insectary during life history studies; *a*, temperature curve; *b*, humidity curve (original)

hatch readily in fourteen to fifteen days, by far the greater number requiring fifteen days. In hatching, the egg cap is pushed up by the head of the emerging nymph, which gradually forces itself out at the top of the shell by aid of the spines on its back. The thin, delicate membranous sack about the nymph is forced up with it and acts as a support for the small, compressed bug while it is expanding and drying out and extending its legs and antennae. This sack-like pellicle is split along the back after the nymph is partially out of the shell and slips off over the head in front carrying the egg cap with it.

The time required from the time the nymph begins pushing up the cap until it is free from the egg is approximately twenty minutes by actual count made on several occasions. The newly hatched nymph begins feeding at once and grows rapidly; at the end of the third day it molts into the second stage. If the temperature is very cool, the time may be extended a day, or even more.

The second stage is very much the same as the first, requiring three days to get its growth, or a day or two longer if the weather is cool. After molting to the third stage, another four days are necessary for the completion of this stage. I have observed a very few to complete the third stage in three days, but by far the greater number require at least four days under very favorable conditions. The fourth and fifth stages each require at least five days for full development with the temperature and moisture ideal.

Thus we see that the time required from the laying of the egg to emergence of the adult, with optimum conditions, is:

Egg	15 days
First instar or stage	3 days
Second instar	3 days
Third instar	4 days
Fourth instar	5 days
Fifth instar	5 days
Total	35 days

This time may be reduced to thirty-three days in a few instances when the egg stage lasts fourteen days and the third instar but three days.

With cooler weather the time from the egg to adult may often be extended to forty-six days, as was shown by several tests made with the immature forms on a small tree placed near the "cold room" from whence a chilly draft constantly passed over the bugs which were on the lower leaves of the tree.

In these experiments adults were isolated in pairs on leaves by means of cloth cages tied about the twigs. The nymphs were very difficult to enclose safely in anything of this type so were isolated as soon as hatched on very small sycamores grown in flowerpots where a careful check could be kept on them.

Females from this first generation were observed to lay their first eggs the eighth day following maturity, thus making the time, from egg to egg, forty-three to forty-five days with temperature and humidity approximating summer conditions.

DESCRIPTIONS OF THE DIFFERENT STAGES

The Adult

Length 3 to 3.75 mm.; width 1.56 to 2 mm. Its shape is roughly oblong-oval, and distinctly flattened dorso-venterally. The elytra (wing covers) and pronotum, or the part between the head and base of wings, are dilated laterally forming a much broadened, gauze or lace-like covering over the body of the insect. This gives a unique and characteristic appearance which serves to identify all members of this group.

The pronotum is produced anteriorly into an inflated bulbous-like hood which covers the head. The outer margin of the prono-

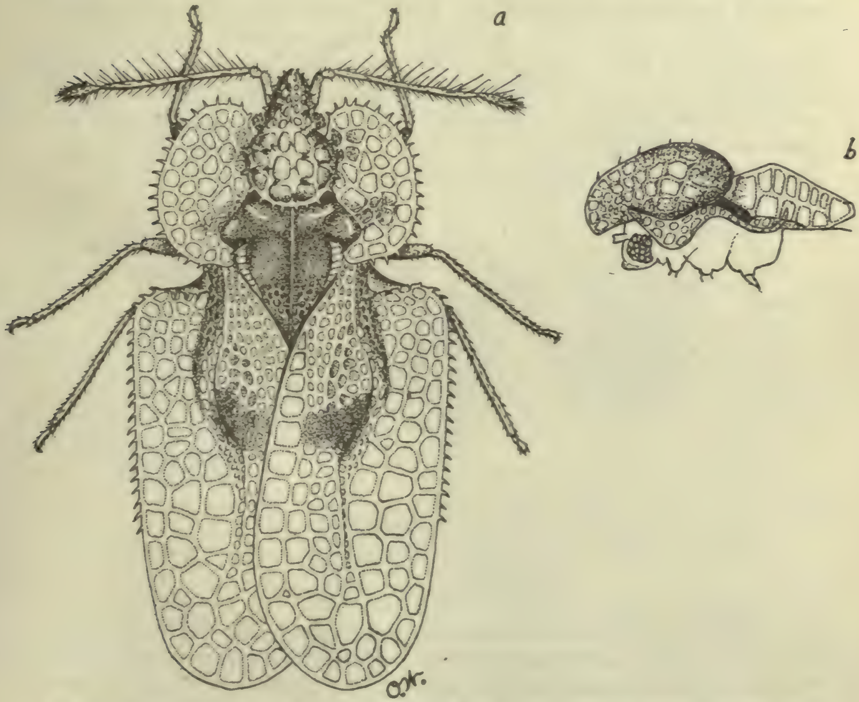

Figure 3—*Corythucha ciliata*, Say: *a*, adult; *b*, side view of hood and median carina (original)

tum and elytra, except the posterior third, bear small, pointed spines; the nervures of the hood, pronotum and elytra are also armed with a few erect spines.

The elytra bear, each a (tumid) elevation near the antero-inner margin. The body is black; the hood, pronotal margins and elytra are whitish except for an irregular brown spot on the tumid elevation of each wing cover.

The Egg

Length .5 mm.; width .16 to .18 mm. Barrel-shaped, rather pointed at the base where it is glued or stuck to the leaf surface. The top is not pointed and is about .1 mm. across with a cone-shaped cap resting on a circular band-like base and bearing on the top a number of ridges which converge from the outer margin to the apex. At the apex is sometimes a thread-like filament, usually short.

Color of egg, pitchy black; color of cap, a dull whitish, though sometimes dark. At time of deposition the female coats the egg with a black, sticky secretion (used to fasten egg to leaf, and pobably serves as a protection) which gives the surface a roughened appearance. The eggshell, with secretion removed, is smooth, shiny black on upper half, as though polished, while the base has a lighter greenish tinge. A group of eggs on the under side of a leaf has an odd appearance, resembling little the eggs of common insects, is usually overlooked and when noticed is oftimes thought to be fungi or just some dirt particles stuck to the leaf.

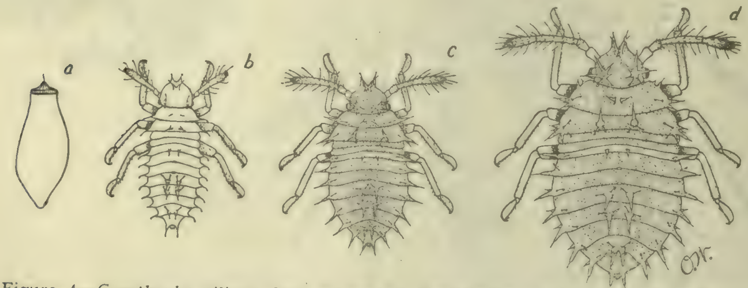

Figure 4—*Corythucha ciliata*, Say; *a*, egg; *b*, first instar; *c*, second instar; *d*, third instar (original)

The Nymphal Stages

The five stages, or instars, are characterized by several features which all have in common, though they may be somewhat modified in the various stages. All the nymphs are armed with spines along the margins of the body and head as well as on the back at different points. These spines are of two main types and quite prominent, no doubt functioning as a protection; this armature gives the nymph a very formidable and characteristic appearance.

In addition to these two general types of prominent spines are many minute spinules on the body surface, except in the first instar on which they do not appear. They are recurved, sharp, width at base almost half the length, and are well distributed over the entire body surface, being especially prominent on the base of the protuberances. These spinules are difficult to distinguish, even with the hand lens, but are quite evident under the microscope, giving the exterior a roughened, granulated appearance.

All the instars are flattened dorso-ventrally, this being especially pronounced in the last three stages, where the aymphs are much broader and more ovate.

At the posterior margin on the mid-dorsal line of the third and fourth abdominal segments are two apertures or openings of the "scent glands". The feet are composed of two segments, a small basal one and a larger, much longer distal one bearing two prominent claws. The last segment of the abdomen is rounded with the tip strongly deflected as if standing on the anal end, when viewed from the side. The abdomen is made up of ten segments.

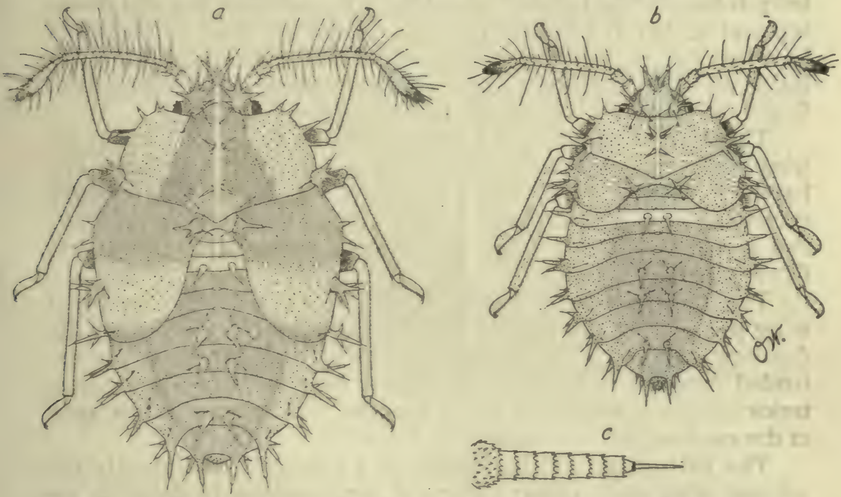

Figure 5—*Corythucha ciliata,* Say; *a,* fifth instar; *b,* fourth instar; *c,* long, cylindrical protuberance showing annulations with minute spinules (original)

Growth of the Young by Molting

After hatching the poung pass through five stages or instars before the adult form is reached. Growth or the increase in size is accomplished by casting the skin or molting as the body becomes too large for it. This takes place by the splitting of the skin at the mid-dorsal line from the head as far back as the second abdominal segment. The head is withdrawn first, the antennae are straightened out and the nymph gradually draws its body from the molted skin. The dorsal spines aid the nymph in breaking the skin and in pulling itself free from it. The act of molting requires from two to four hours, and a newly molted nymph is creamy-white, not assuming its normal dark brown color for several hours after it has left the old skin.

Distinguishing Characters of the Different Stages

The first stage can always be recognized by its more slender, less flattened appearance, the absence of long, spine-bearing protuberances, and by each spine having a blunt tip which is usually enlarged and rounded. The minute spinules found covering the body surface in the succeeding instars are absent in this stage. But five facets are present in each eye.

The second stage still has only the one spine on the lateral margin of each of the abdominal segments two to nine, but it now arises from an elongated protuberance instead of a conical base and is pointed, while just inside of this is a trumpet-shaped spine. The body is broader and darker in color. The antennae are still three-segmented, but the lateral margins of the pro and meso-thorax bear two spines on protuberances and a trumpet-shaped spine just inside of these instead of the single blunt spine on a conical base found in instar one. Each eye has six or more facets.

Ths third stage now has four segments in the antennae, but the wing pads are not developed beyond a faint enlargement. The lateral margins of abdominal segments two to nine have three spines, one on a protuberance, one arising from a conical base, and a trumpet-shaped spine just inside of these. Each eye has fifteen or more facets.

The fourth stage is easily recognized by the well developed wing pads which are oval in outline and reach to the second abdominal segment. The anterior margain of the pronotum is extended forward to the eyes, or slightly over them, while the posterior margin is produced into a rounded triangular point or apex at the median line.

The fifth stage will be known at a glance by the greatly developed wing pads, rather elongated and reaching to the fifth abdominal segment. The anterior margin of the pronotum at the median line is raised and extended a little forward while the posterior margin is quite distinctly triangular. The lateral margins of the abdominal segments one, two and three are without spines.

METHODS OF CONTROL

Natural Enemies

There are a number of predatory insects which prey upon the young of the sycamore lace-bug, but seemingly none to so great an extent as to make them an important factor in the reduction of the numbers of this pest. Among those which I have taken while feeding on the nymphs were one immature Chrysopid, several assassin bugs (*Reduviidae*), a few spiders, and a red mite (unidentified). This mite is found attached to the head or body and does not appear to be a common parasite on this host.

Undoubtedly there are other forms, such as lady-bird beetles (*Coccinellidae*) and ground beetles (*Carabidae*), which prey upon them to a greater or less extent, but of these I have never observed any in the actual act of feeding upon the young. Morrill reports "The adult form a well known predaceous heteropteran—*Triphleps insidiousus*, Say—has been found feeding on the young of *C. ciliata*".

Insecticidal Measures

Since this species is a hemipteron with the characteristic piercing suctorial mouth parts, it is at once apparent that an effective insecticide would have to be a contact spray. Experiments were conducted during July and August (1916) at Oklahoma City in the Oklahoma City Nursey and in Belle Isle Park.

The first difficulty encountered was to apply the sprays so that all adults would be reached, as at the first disturbance caused by the spray striking the leaves, they would dart about in all directions, making it rather difficult to reach every one of them. Then while it is comparatively easy to kill the immature forms, it is quite difficult to accomplish this with the adults without getting a solution strong enough to injure the leaves or make it prohibitive in price.

Due to the unique and characteristic lace or gauze-like structure of the wings and thorax, which covers the entire body effectively, anything but a caustic penetrating liquid will not reach the spiracles or more vulnerable parts of the body.

The following mixtures were used and with the results recorded below:

Kerosene Emulsion

Laundry soap or fish oil soap	½ pound
Kerosene (coal oil)	2 gallons
Water	1 gallon

(Crude oil may be substituted for kerosene.)

The soap is shaved into thin slices and added to the gallon of boiling water and stirred until a good suds is obtained. It is then removed from the fire and the kerosene is added and the mixture is thoroughly emulsified until it makes a smooth, creamy liquid with no free particles of oil floating on top. This stock solution was diluted to a 10% strength of oil by adding 1 part stock solu-

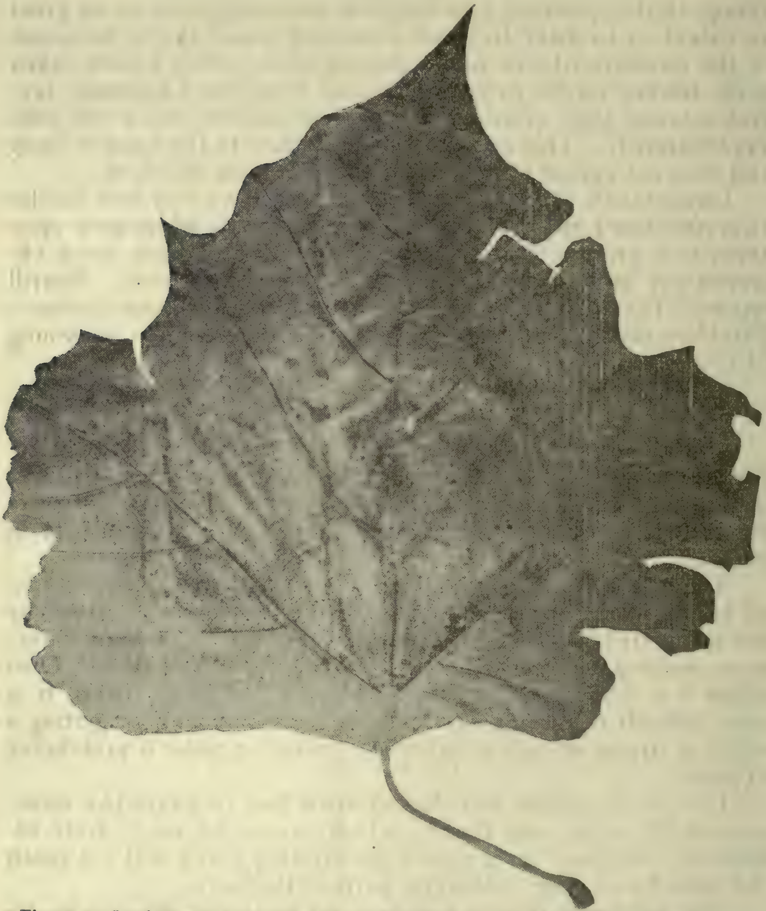

Figure 6—Leaf showing nymphs and adults killed by the kerosene emulsion spray (H. R. Painter)

tion to 5 2-3 parts water and applied to the under surfaces of the leaves.

The results were quite favorable in most applications, accomplishing the destruction of all the young, and from 80% to 90% of the adults. However, in a few instances the foliage of some of the trees was burned slightly, indicating that a stronger solution would not be safe. This strength should not be used except on bright, sunshiny days when there is a slight breeze in order to volatilize the excess oil and prevent severe burning of the leaves, otherwise there may be great injury to the foliage, and if used at a weaker strength it is not effective enough for the adults to warrant its use in this case.

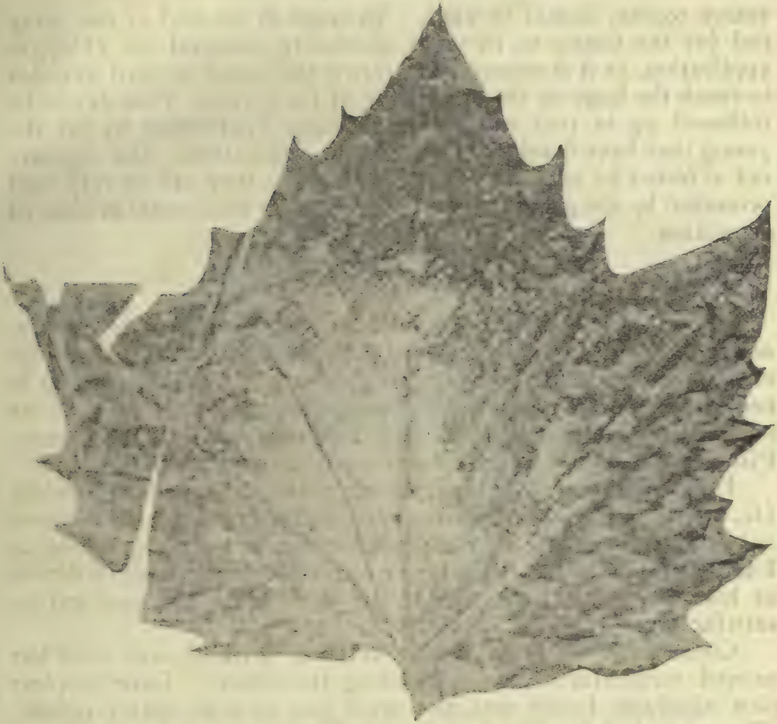

Figure 7—Leaf illustrating whitish, deadened condition caused by the sycamore lace-bug (H. R. Painter)

Fish Oil Soap Solution

This solution was used and with excellent results, being almost a perfect control for adults as well as the immature forms when carefully applied. It gave much better results than any other formula tested, and with no disastrous results to the foliage. It is safe to use at any time and has excellent spreading and penetrating qualities:

Formula Used

Fish oil soap	1 pound
Water (preferably soft)	6 gallons

To prepare this, shave the soap into a small quantity of boiling water and stir until it is well dissolved, then add enough water to make the proper proportion and thoroughly mix by pumping the solution into the spray tank.

To effectively apply this spray, a pressure of at least 150 pounds is necessary and a nozzle of the larger disk type which throws a large, even, hollow or solid, cone-shaped spray, and rather coarse, should be used. An angle at the end of the spray rod for the nozzle to fit on is absolutely essential for effective application, as it is necessary to throw the liquid upward in order to reach the bugs on the under side of the leaves. This should be followed up in two weeks with another application to get the young that have hatched after the first application. The eggs are not affected by any spray that was used as they are so very well protected by the gluey substance secreted by the female at time of deposition.

Nicotine Sulphate

Several brands of nicotine sulphate were used, containing 40% active nicotine, at the strength of 1 to 700 and 1 to 600, but with unsatisfactory results. When used, a small quantity of soap is necessary as a spreader and sticker as the nicotine alone collects on the leaves in small drops and does not reach all the insects. Fish oil soap added to the tobacco decoction enhances its value.

Fink in his control experiments with the eggplant lace-bug (*G. solani,* Heid) also records unsatisfactory results with nicotine sulphate as a control for the adult forms when used as strong as 1 to 600. The writer hesitates in recommending tobacco solution as his results from the use of the same were not uniform or satisfactory.

Concentrate commercial lime sulphur, 1 to 40, was used but proved unsatisfactory in controlling the adults. Lime sulphur plus nicofume liquid was also tried out with no better results. The proportion used was, concentrate lime sulphur 1 quart, nicofume liquid ¼ pint, water 25 gallons.

Conclusion.—Results from the tests made indicate the fish oil soap solution to be the most practical and effective, and when carefully applied with a good spraying apparatus, it should be as economical as the other solutions tested, if not cheaper.

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University of Maine

Maine Agricultural Experiment Station

ORONO

BULLETIN 263 AUGUST, 1917

SYRPHIDAE OF MAINE—SECOND REPORT

CONTENTS.

This bulletin discusses the life history of the following beneficial Flower-flies, all of which feed in the larval stage on aphids:

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* Absent on leave during period of war.

† In collaboration with U. S. Department of Agriculture.

BULLETIN 263

SYRPHIDAE OF MAINE.

SECOND REPORT: LIFE HISTORY STUDIES.[1]

C. L. METCALF.[2]

The investigation of the biology, ecology, and economic status of the Flower-flies of Maine, the first report of which appeared as Bulletin 253 of this station, has been continued during the summers of 1916 and 1917. The data secured on the following species seems of sufficient interest to warrant publication at this time.

The species discussed below are all aphidophagous, depending for growth and development on aphids, which are ravenously devoured during the larval stage of the fly. They must therefore be recognized as beneficial insects and their presence in any locality must be looked upon as an agricultural asset of no mean importance. To illustrate,—in an experiment with one of the species described below (see page 156) the writer found that, in five hours less than two days, three larvae had devoured a total of 325 plant-lice, or an average of not less than 54 a day for each larva. There is no reason to believe that this record is in any way exceptional. In fact in this case the thoroughness with which the aphids were devoured indicated a still greater capacity of the larvae.

So far as I am aware no previous record has been made of the metamorphoses of these species.

The species, *Syrphus oronoensis,* appears to be an important predator of the aphids affecting stone fruits; the species *Xanthogramma divisa* and *Syrphus* ***knabi*** are, so far as observed, of more benefit to certain shade and forest trees; while the chosen food of *Platychirus perpallidus* has not been determined.

The latter species is of faunistic interest since it is not hitherto recorded outside of Britain. I have also taken the following European species of *Platychirus* in Maine: *P. scutatus* Meig.; *P. immarginatus* Zett.; *P. discimanus* Loew (Dr. Edith M. Patch, collector); and *P. angustatus* Zett.

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[1] Papers from the Maine Agricultural Experiment Station: Entomology No. 94.

[2] Member of the Station Summer Staff.

It is of particular interest to record species of the two genera *Platychirus* and *Xanthogramma* as aphidophagus since they have each been recorded as having species which are scavengers in the larval stage. These two genera should be added to the list of ten genera given in the author's previous bulletin as aphidophagous, at least in part.

The Aphididae named in this bulletin have all been determined by Dr. Edith M. Patch, Entomologist. The writer is also indebted to Messrs. W. F. Pride, Geo. B. Newman and Robert K. Fletcher for assistance in collecting and caring for material.

XANTHOGRAMMA DIVISA Williston.

This is an aphidophagous species occurring sparsely in the larval stage among aphids on a number of our shade and forest trees, and occasionally increasing to abundance when a favorable infestation of aphids is available.

It is the handsomest larva of Syrphidae that I have seen and all stages present interesting structural characteristics.

Verrall[1] says of the genus: "Not much is known about the metamorphoses, but the larva has been reared from heaps of turf," so that the members of the genus have been believed to be scavengers. However, a report of the Hawaiian Sugar Planter's Experiment Station gives a photograph of the adult of a species of *Xanthogramma* among the predaceous insects of the island.

The records of the immature stages are as follows:

A well-grown brown larva collected by Mr. W. F. Pride, July 6, 1915, among *Aphis cerasifoliae* Fitch on choke cherry *(Prunus virginiana)*, succumbed in the laboratory after a long-drawn-out period of slow starvation, during which it failed to pupate.

A very small larva collected on *Cornus* sp. *(Aphis cornifoliae* Fitch), July 12, 1915 was ashy-gray in color instead of brownish. It was fed in confinement from *Aphis cornifoliae* and in about a week had attained full size and become a beautiful tan in color. It was fed every other day until July 31, when it was placed out-of-doors on the original *Cornus* leaves, inside a cheese-cloth bag. Here it remained without striking change, gradually becoming dryer and more attenuated, until Sept. 12 when it was recovered but later died.

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[1] Verrall, G. H., British Flies, Vol. VIII, Syrphidae, p. 448.

On July 24, 1916, Mr. G. B. Newman collected a nearly full grown, and three very small, larvae of this species among *Chaitophorus populicola* Thomas on poplar. The smaller ones were decidedly greenish in color, the large one tan. This green color gave place in the laboratory to an ashy- or faint-green which persisted for a week or more. On August 2, two of them were decidedly tan colored and by August 5 all had become so.

There was as yet no clue whatever to the identity of the larvae under consideration, and it proved a most difficult species to rear. Those kept in pint jars in-doors, even when most attentively supplied with their chosen food, fresh daily, fed and grew rapidly to full size, and then gradually became senescent, more and more sluggish, and after a time refused to feed or to move or to pupate, becoming more and more attenuated, thinner and dryer, and moving about only when disturbed until months later when they appeared finally to be lifeless. Sterile soil and decayed wood were provided in the bottom of the cages for pupation but without success. Much the same experience resulted from attempts to rear them in field cages or cheese-cloth enclosures on the living infested plants out-of-doors.

On August 8, 1916 a number of eggs were found in company with a dozen or so of larvae of various sizes scattered along the smaller twigs of willow trees infested with *Pterocomma smithiae* (Monell). These eggs began hatching on August 13 and at once disclosed the fact that they were conspecific with the flattened brownish larvae. The eggs, while of about the average size for this group, presented a microscopic spider-web sort of pattern on the chorion which was so characteristic that, in view of the difficulty of rearing adults from the larvae, the attempt was at once made to capture gravid females which should disclose the same kind of egg and so accomplish the determination of the species.

Finally on August 25, Mr. Newman captured about one of the infested trees a female of *Xanthogramma divisa*. She was confined indoors about 10 A. M. and by 2 P. M. had deposited a single egg, another by 2.45 P. M. and four more during the next hour. She died over night without any further oviposition; but the few eggs were sufficient to establish the identity of the unusual larvae. These eggs hatched in the laboratory between 8 A. M. August 28 and 8 A. M. August 29, and speedily developed into larvae of the characteristic appearance.

The first puparium was formed August 24 in moist earth in the bottom of the jar confining larvae collected August 7 from willow; two others August 27 and two others August 29.

The first adult (from a puparium formed August 27) was disclosed Sept. 12; the others during shipment from Maine to Ohio between Sept. 13 and 20, the exact date not determined; except for one specimen which yielded a parasite (species undetermined) some days later.

Noting the voraciousness of the young larvae of this species the following tests were made of their capacity for destroying aphids:

Sept. 7, 9.30 A. M., three larvae were enclosed with 150 aphids of *Pterocomma smithiae*. At 8 A. M., Sept. 8, not a single whole aphid, living or dead, was found in the vial,—nothing but the cast-off skins. In other words each of the three larvae had devoured, on the average, 50 aphids in 22½ hours. At 11.40 A. M. of the same day the same three larvae were enclosed with 175 aphids of the same species, some of them actively reproducing. At 5 P. M. many of the aphids were still living, but by 8 A. M., Sept. 9, all had been devoured, most of the feeding in this case having taken place at night.

On August 31, another female was captured in the field about the infested willow but was slightly injured and died before ovipositing.

On Sept. 1, several full-sized larvae were found under loose pieces of dead bark on the infested willow trees, presumably seeking a site for pupation and possibly for hibernation. The larvae taken into confinement however died without pupating.

On my return to Orono, June 7, 1917, an examination of the trees, infested the previous season disclosed four puparia, three of them glued to loose pieces of bark on the trunk or principle branches of the tree, the other on the ground among fallen pieces of bark.[1]

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[1] It may be noted that the puparium found on the ground is the only one of the lot which failed to yield either a living fly or parasites; this specimen (a male) died without emerging.

From one of these puparia left out-of-doors, a female emerged June 18, another June 22, while a third disclosed 26 parasites (undetermined) July 8th, the entire lot emerging from a single small hole gnawed thru the anterior end of the puparium (Fig. 9, B). The exact date of pupation, i.e., whether the full-grown larvae passed the winter, pupating in spring, or whether pupation occurred sometime in autumn has not been determined,—probably the latter. Several full-grown larvae were collected by Mr.Fletcher among *Myzus cerasi* (Fab.) on cherry, July 18, 1917.

It appears likely that there are two more or less complete generations of this species, annually, though not occurring in very definite broods. Adults from overwintering larvae or pupae evidently giving rise to the larvae which have been found full sized by early July; and the adults from these larvae producing another generation, the larvae of which occur especially during August. A partial third generation from eggs deposited by females visiting the colonies of aphids the last week in August, seems probable.

Egg (Fig. 8, A). Lengths of seven eggs measured were 0.861, 0.8815, 0.89175, 0.9225, 0.9532, 0.975, and 0.9942 mm., respectively, the average 0.925 mm.; their greatest diameters were respectively 0.3075, 0.308, 0.315, 0.328, 0.3375, 0.3485, and 0.3485 mm., the average 0.3275 mm.

The egg is of about the usual sub-cylindrical shape, somewhat inflated in the middle and with the micropylar end a little smaller and more truncate than the opposite end; also with the ventral surface flattened somewhat to the twig on which it is deposited. Color white, glistening.

The characteristic thing is the sculpturing of the chorion the microscopic pattern of which (Fig. 8, B) suggests at first glance a very large number of minute, 8-rayed spider webs, or hexagonal wheels, contiguous to each other, with a very small elevated body in the center of each. Taking each "web" as a unit it may be described as consisting of a very small, sub-conical, elevated body in the center of the web (the hub) from which radiate eight, slender, slightly elevated arms arranged in four pairs. The two arms extending from the central elevation, or hub, toward either pole of the egg, radiate like the spokes of a wheel; while the two which extend in the transverse direction from either side of the hub (i. e. perpendicular to the long axis of the egg in a plane parallel to it) run practically parallel to each other. A series of these *parallel* arms, together with the hubs they connect make a ladder-like chain running almost transversely (sometimes somewhat obliquely) around the egg. The individual units are closely contiguous to each other so that each arm forms a spoke for two central bodies or hubs, and the rim of the imaged wheel is formed only by adapting the contiguous spokes of adjoining wheels. The pattern is of such a size that about forty of the ladder-like chains are traversed in passing from one pole of the egg to the other, the elevated bodies being approximately 0.02 mm. apart.

The eggs have been taken in the field only on the small twigs of willow directly among the aphids, *Pterocomma smithiae* (Monell), in early August. They were also deposited in captivity from a female caught hovering about this infestation in late August. There is at least one other time of occurrence for the egg stage, those giving rise to the first generation of larvae in the spring probably being deposited in June. It is further probable that adults emerging in September, (as specimens in the laboratory did) may deposit eggs for a third generation; although it seems doubtful if these larvae could mature at this latitude before cold weather cut short their food supply.

The eggs are glued by the ventral surface to the bark of the young twigs, and occur singly.

The duration in the egg stage, from eggs deposited indoors, was between 2⅔ and 3¾ days, while some eggs brought in from the field on August 8 did not hatch until August 13, this stage exceeding five days. At time of hatching the micropylar end of the egg shell is pushed off as a roughly circular cap, leaving the rest of the shell intact.

Larva (Fig. 8, C to H). The newly hatched larva (Fig. 8, C) is elongate ovate in outline with the posterior end truncated or even excised. It measured 0.95 mm. in length by 0.39 mm. in its greatest width, a little caudad of mid-length. It thus appears, from the first, proportionately broader and is more flattened than the other described aphidophagous species. The color is pale yellow more or less blackened on the mid-dorsal line by the interrupted pulsating dorsal blood-vessel. The whitish longitudinal tracheal trunks also are faintly visible thru the integument. The young larva appears very bristly (cf. *Syrphus americana* Wied.[1]), the segmental bristles being quite conspicuous. There are eight transverse rows of twelve bristles each, besides additional ones on the terminal segment, the individual setae measuring about 0.0666 mm. in length,—of two segments, the basal one about 0.008 mm. long and of equal diameter, the distal one 0.06 mm. long and about 0.0035 mm. in diameter, tapering slightly to the tip. The integument is wrinkled transversely and the lateral margins are irregularly serrate.

The posterior respiratory tubes are well separated, fairly prominent, nodular; the slit-like spiracles short and situated near together. There is no integumental vestiture in addition to the segmental setae.

As growth continues the larva becomes more and more flattened so that by the time it is full grown it is more than half as broad as long, measuring 10 to 11 mm. in length by 5 to 5½ mm. in maximum width, and only about 1⅓ mm. in height.

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[1] The Ohio Naturalist, Vol. VII, No. 5, p. 479, Mch. 1912.

Very different in shape from the usual aphidophagous larva, suggesting somewhat the larva of *Microdon* and indeed forming a most interesting intermediate step, structurally, between the typical aphidophagous larva, such as *Syphus americana, S. torvus, Sphaerophoria cylindrica,* and others and the extremely specialized larvae which live in the nests of ants.

When the larva is resting its shape from above is broadly ovate, somewhat narrower and less truncate at the anterior end. The entire lateral and anterior margins are deeply serrate, there being three large and subequal and one much smaller serration to each of the seven principal segments (Fig. 8, F & H). The three larger serrations bear at their tips the lateral, posterior ventro-lateral and anterior ventro-lateral segmental spines; the median, dorsal and dorso-lateral ones retaining their normal positions on the dorsal surface of the somites. The fourth and smaller serration is nude of bristles. Each of these principle serrations, or lateral, cone-shaped processes, is covered with papillae similar to those over the entire dorsum of the larva, so that in outline they appear secondarily serrated with ten or a dozen papillae on each side. The segmental spines are pale, colorless, of the usual two segments, the basal one 0.035 to 0.04 mm. in length and of about equal width, the distal one peg-like, 0.055 to 0.075 mm. in length, by 0.015 to 0.0185 mm. in diameter, accuminate toward the tip. The median, dorsal, and dorso-lateral spines are considerably smaller, measuring not more than 0.05 mm. in length, and exceedingly inconspicuous, it being almost impossible to detect them in the dorsal view, though visible at good magnifications in profile (See Fig 8, D).

The anterior segments, retracted under segment four when the larva rests, are, when it is active, protruded as a blunt, cone-shaped projection bearing dorsally the anterior spiracles and, terminally, the retractile antennae and mouth parts. As seen in caudal aspect (Fig. 8, D) or in cross-section the larva is very broadly sub-triangular, the apex of the triangle being at the mid-dorsal line and the lateral margins bearing the fringe of serrations already described.

The length of the posterior respiratory organ of the larvae measured, (Fig. 8, E, G) varied from 0.8625 mm. to 0.9525 mm., with an average of practically 0.9 mm.; the width at the tip varied from 0.4875 mm. to 0.5025 mm., averaging 0.494 mm.; the height at the tip ranged from 0.2625 mm. to 0.285 mm., averaging 0.27 mm. The median, slit-like spiracle ranged in length from 0.1275 mm. to 0.1387 mm. (averaging 0.134 mm.) by 0.015 mm. in width. The diameter of the circular plate varied from 0.0675 to 0.075 mm. averaging 0.0712 mm.; and these are situated with their median margins from 0.08 to 0.09 mm. apart. The color of the respiratory tube is brown, its surface rugose, with a shallow impression on the median line and a very moderate incision between the stigmal plates. The dorsal spiracular spine is very inconspicuous but the other interspiracular spaces bear broad rugose carinae, somewhat more elevated than the slit-like spiracles.

The integument of the larva is glabrous, finely and regularly papillose, very thin and transparent. The colors of the larva which are therefore resident in the viscera, are during development either an ashy or yellowish green, or more often, a yellowish brown. The young larvae collected from poplar were at first a delicate pea-green but soon changed indoors to the pinkish buff; and all the larvae found on willow at whatever age, as well as those reared indoors from the egg were constantly tan-colored. The full grown larva in any case is "tan-colored," a salmon buff or pinkish buff or warm vinaceous, the dorsum being mostly covered with small, globular masses of adipose tissue of this color. Where these globules are wanting the color is black as follows: A faint, interrupted, black, mid-dorsal line; and an irregular, elongate, blackish spot, obliquely-placed on either side of each of the principle segments; about six such spots on each side of the body running from near the mid-dorsal line obliquely laterad and caudad to the lateral margin. Sometimes these black blotches are so large as to give the larvae a prominent, V-shaped, banded appearance, the apex of the Vs directed cephalad on the middle line.

Growth is rapid, the young larvae apparently reaching full size within ten days of hatching. They are quite active and voracious during this time, moving about over the willow twigs tirelessly if the aphids are scarce.

However the full-sized larvae are exceedingly sluggish and apparently pass thru a pre-pupal period, from a week to several weeks, during which there is little or no feeding or motion.

The larvae were found on the under side of the leaves of wild cherry, poplar and dogwood, but on willow almost exclusively on the young twigs, their location being determined of course by the position of the aphids attacked. They appear to be quite rare during the first half of the season but occurred in abundance during August, 1916 on willow.

It seems likely that this may be the species referred to by C. W. Johnson in Psyche Vol. XIII, p. 3, Feb., 1906, as follows:

> "Figure 7 represents a larva found by Mr. Owen Bryant at Cohasset, during the latter part of September, among some "woolly" aphids on the wild lettuce (*Lactuca elongata*). The larva was very flat, about 7 mm., in length, slightly roughened, and of a dull yellowish color. It evidently belongs to the Syrphidae. I did not succeed in getting it to pupate."

Puparium (Fig. 8, I, J). Length 6.6 to 7.75 mm., average 7 mm.; including the posterior respiratory organ, 7 mm. to 8.2 mm., average 7.6 mm. Width 3.5 to 4.1 mm., average 3.87mm. Height 2.3 to 3 mm., average 2.75 mm. In outline elongate oval with nearly parallel sides, the margins prominently serrated with the somewhat shrunken lateral processes of the larva, slightly widest a little caudad of the middle. Similar to the larva but the anterior end somewhat narrowed and considerably inflated dorsad.

It is noticed that the anterior end of the larva is but little retracted caudad on the ventral line; the larval mouth-parts remaining near the anterior pole of the puparium.

As seen from the side the anterior face is a little less than perpendicular rounding dorso-caudad to reach the greatest height about the anterior third. The dorsal line continues convex to a little beyond mid-length whence it is usually more or less concave to the tip. The ventral line is gently concave in the anterior two-thirds, thence straight or convex. As seen from in front, the outline is considerably flattened on the ventral side.

Color and pattern at first similar to that of the larva but soon loosing the warm tan or vinaceous and becoming a colder, dull clay color. The pupal envelope becomes marked with six or seven prominent transverse blackish bands not reaching the side margins, expanding a little on the middle line and irregularly prolonged backwards, hooklike, at their outer ends. The anterior ones are broader, the posterior ones narrower,—without the lateral expansions, and stopping much short of the lateral margins.

Adult (Fig. 12, K). The specimens so far reared from these larvae are all females. Of the described species they fit most nearly the *Xanthogramma divisa*[1], of Williston though in some respects they agree rather better with *X. felix* O. S. If these should prove synonymous, as Williston thought possible, the species would take the older name *felix*.

I quote Williston's description with emendations to apply to the specimens reared:

"♀. Length 9 to 11mm. Face and cheeks yellow or reddish yellow" with an opalescent reflection. "Face nearly perpendicular, gently concave below the antennae, and with a large obtuse tubercle below," from which the face retreats, being not at all produced again to the upper mouth edge. Labellae yellow. "Front above metallic greenish black, continued as a broad stripe to the base of the antennae," (the stripe occupies only about one-third the width of the front) "somewhat expanded below; on the sides yellow. Antennae black; somewhat reddish below on the sides of the second, and of the third joint near the base." The yellow is more extensive in my specimens, occupying much of the first and second joints and a large area on the under side of the third. "Dorsum of thorax deep metallic green with rather ill-defined yellow lateral stripes. Pleurae with a large ill-defined spot. Scutellum a somewhat translucent yellow, its base" very "narrowly black."

Abdomen opaque black; first segment broadly yellow on the sides encroaching minutely on the anterior corners of the second segment.

"Second segment with an oval spot on each side," two-and-a-half to three times as long as broad, the outer end cut off parallel with and "not reaching the lateral margin, somewhat attenuated toward the inner end." The spots separated by two-thirds their maximum width, or about ⅓ mm. "Third and fourth segments with large rectangular spots" a little longer than those on the second segment and the posterior lateral and median corners both somewhat rounded off, these spots separated by a third to a

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[1] Proc. Am. Phil. Soc., XX, 311.

half their width (those on the third segment are from 0.15 to 0.22 mm. apart, those on the fourth 0.23 to 0.27 mm.) "and not quite reaching the lateral margin." The anterior lateral corners of these segments are narrowly yellow, the posterior margin of the third narrowly so in the middle and of the fourth more broadly. Fifth segment with an arcuate black band reaching the anterior margin in the middle, leaving the posterior margin, more broadly in the middle, and the anterior corners yellow, which latter make with the yellow of the preceding segment an arcuate yellow band attenuated in the middle. Venter yellow except for small black patches at the posterior corners of the principle segments. Legs rather more yellowish than in Williston's specimens, the anterior and middle pairs being entirely yellow, the hind ones infuscated somewhat on the middle of the femur and from the basal third of the tibia outward. "Wings hyaline, with a slight smoky tinge; stigma yellowish."

In all my specimens the abdomen reaches its greatest width at the tip of the second segment, which Williston states is characteristic of his specimen of *felix,* but the yellow spots of the abdomen are much too widely and distinctly separated to fit Osten Sacken's description of *felix.*

No adults have been taken in the field except the two females mentioned above which were captured about aphid colonies. However I have an Ohio specimen which agrees with the Maine specimens in detail.

SYRPHUS ORONOENSIS n. sp.

Larva (Fig. 10, A). Length about 11 mm., width 2.5 to 3.5 mm., height 1.5 to 2.5 mm. In outline the larva may be described as very elongate, subtriangular; somewhat more flattened than the ordinary aphidophagous larva, being sub-triangular in cross-section. The lateral margins are serrated and the posterior end convex rather than truncate.

Conspicuously colored, the posterior two-thirds or three-fifths of the body being chalky white, except along the margins; the anterior third or two-fifths as well as the entire lateral margins and the terminal segments, bright tan, maroon, or even quite black, depending on the stage of development of the larva. This sharp contrast of colors gives to the larva an appearance quite suggestive of bird-droppings especially when found curled about small twigs.

A more detailed examination of the color and pattern, which appears to vary only in details, shows that the anterior segments of the body vary from dark greenish gray to black as a ground color, with a median narrow stripe of white in segments four, five and six, and more or less extensive mottling with clusters of globular adipose bodies which vary from tan to dark maroon, the lighter colors prevailing on the younger larvae. The darker colors which occupy all except the narrow, mid-dorsal line throughout the first six segments, become restricted to progressively narrower and narrower lateral margins throughout segments 7 to 11, but again occupy the entire dorsum in segment 12.

The chalky-white median line of adipose tissue, which is scarcely a third of a millimeter wide throughout the anterior segments, *ends abruptly between segments 6 and 7 where the body is always quite blackish in larvae of all stages. On the anterior part of segment 7, the white adipose mass begins again, quite as abruptly,* with two U-shaped loops opening caudad, and separated by the black heart-line; the white mass occupying perhaps a third or fourth of the body width in segments 7 and 8. In segments 9 to 11, inclusive, the white masses expand in laterally-directed, angular wings to occupy four-fifths or more of the width. The large mass is not uniformly white, but is interrupted in each segment from 9 to 11 by the pulsating black heart-line and at the sides of this by large irregular pockets and smaller areas of greenish gray where the body fluids are unobscured by the globular masses of white. In very young larvae, the whole mass above described as white may be more or less tinged with tan. The venter is maroon to black, the margins whitish.

The transparent integument is uniformly papillose but without integumental vestiture. The segmental spines are small, light in color, and only moderately elevated, 0.045 to 0.075 mm. long, of two sub-equal, sub-cylindrical segments, the basal one 0.025 to 0.03 mm. in diameter, the distal one half as broad. The body wrinkles are moderately prominent. The posterior respiratory organ (Fig. 10, D, E) is very characteristic, being considerably longer than in the described members of this genus. *About two-thirds the distance from the base is a prominent constriction,* the tube being much depressed and somewhat compressed at this point. The basal two-thirds is very rugose with rounded papillae and dark maroon or black in color, while beyond the constriction the tube is smoother, polished and light brown in color. The entire respiratory organ measured as follows: length 0.702, 0.756, 0.756, 0.878, 0.918, 0.922 mm., the average 0.822 mm.; width at base 0.41 to 0.54 mm., the average 0.485 mm.; width at tip 0.325 to 0.35 mm., the average 0.334 mm.; height at base 0.35 to 0.43 mm., the average 0.54 mm.; height at tip 0.164 to 0.189 mm., the average 0.173 mm.

The stigmal plates are somewhat divergent at the tip with a noticeable emargination between them, the slit-like spiracles only moderately elevated and short measuring 0.055 to 0.06 mm. in length by about 0.02 mm. wide.

The rugose, black, dorsal spiracular spine is rather prominent, elongate dorso-ventrad, somewhat crescent shaped and bending laterad somewhat over the circular plate. The latter is very inconspicuous and appears to be elongate dorso-ventrad and narrower at the ventral end, rather than round. In each inter-spiracular space is a slight ridge with a single, tiny, whitish hair about 0.015 to 0.02 mm. long arising from a minute circular crater.

These larvae are aphidophagous, having been taken first in early July, 1916 at Orono on a willow infested with *Pterocomma smithiae* (Monell). In captivity one pupated July 28, the adult emerging August 6. Another pupated a few days later and on August 12 a puparium was found in the field, glued to a small twig of willow near an infestation of this aphid; this specimen emerged August 13. Full grown larvae were again found on August 27 among the same species of aphid.

In 1917, on June 29, Mr. R. K. Fletcher and the writer found a number of larvae among *Myzus cerasi* (Fab.) on cultivated cherry and among *Phorodon humuli* (Schrank) and *Rhopalosiphum nympheae* (Linné) on cultivated plum. These varied from larvae but recently hatched to full grown, all of which showed the characteristic pattern described above, the younger larvae however being lighter in color. Pupation of these larvae began July 8th. The type female emerged August 2 from a puparium formed July 24.

There thus appears to be at least two generations of this species annually, one occurring as larvae chiefly during June, the other occurring in the larval stage chiefly during August. A one-fourth grown larva was taken among *Myzus cerasi* (Fab.) on July 14, indicating that the generations are somewhat irregular.

The larva does not appear to be much restricted in its choice of food, the known hosts representing four different genera.

It is a species offering considerable possibilities in the control of aphids affecting the stone fruits and its ability to live on aphids of other hosts is at least an advantage in the maintenance of the species.

The larvae are to be found on the under, infested, side of the leaves of the trees mentioned and also on the smaller twigs. With the green of the leaf as a background or when removed from their natural surroundings, their colors make them quite conspicuous. But when surrounded thickly by aphids or, more especially, when wound around a small infested twig they are quite inconspicuous. When I first found the larva on an uninfested twig, in which situation they appear to pupate, I was strongly impressed with its resemblance to the droppings from a bird.

Puparium (Fig. 10, B). Length about 7 mm., exclusive of the posterior respiratory organ which may project half a millimeter farther or be directed more dorsad. Maximum width 3.25 mm., maximum height 2.75 mm. The anterior half is irregularly globose, the puparium somewhat suddenly depressed about mid-length, the posterior half remaining flattened much as in the larva. It is interesting to note that this depression, or lack of inflation, begins at the point on the seventh larval segment where the white adipose mass gives way to the black area of segment six. The puparium is widest about 2 mm. caudad of the anterior extremity, or in the region of the fifth and sixth larval segments which are of about equal width in the puparium. Anterior to this point the outline from above is unevenly rounded. Cephalad of the fifth segment the puparium narrows noticeably to a width of 2.25 mm. in half that length and in front of this constriction the outline is semicircular. Caudad of the sixth segment, or widest point, is a similar constriction to a width of about 2.25 mm. at the beginning of the eight larval segment. From this point the body is more regularly attenuated; and the puparium, inflated a little at each segment, narrows to a width of 1.25 to 1.75 mm. at about half a millimeter from the posterior end. Thence it is rapidly attenuated to the respiratory organ, if this is terminal, or is more nearly truncate if the respiratory organ is directed dorsad. As seen from the side the ventral line beginning with the region of the larval mouthparts is at first gently convex downward, then more or less strongly concave to a point well caudad of the middle, thence again convex to the posterior end. The dorsal line is strongly and evenly convex dorsad and caudad to about the region of the seventh larval segment, about three millimeters caudad of the anterior end. It is then abruptly depressed or concave throughout segments seven to nine and finally gently convex to the posterior end. The shape as seen from in front is a short oval with the long axis transversely and spherical angles at the sides. The posterior half of the body retains the shape of the larva to an unusual degree and is sub-triangular except that in some specimens the lateral margins show moderate dorsal carinae.

The predominating color of the puparium is maroon to black, extensively mottled with patches of white and of pinkish brown. The dark middorsal line of the larva is evident over the posterior half of the puparium, and is bordered with more or less extensive irregular masses of the white adipose tissue of the larva. In the region of larval segment six is usually a large dark area, while in front of this the color is quite dark, overlaid with irregular areas of lighter color. The posterior end of the puparium, including the base of the respiratory organ is almost black, the distal end of the latter brown.

Syrphus oronoensis n. sp.

Adult (Fig. 10, C). ♂. A small species, the abdomen with nearly parallel sides, the three principle segments opaque black and each with a pair of yellow sub-triangular spots, the first pair small and far apart, the others larger and more approximate.

Length about 8 or 9 mm. Head large, broader than the thorax or abdomen. Eyes bare. Frontal triangle somewhat swollen, bronze black, shining, with rather long black pile which continues somewhat thickly down the sides of the face to the mouth edge. Vertical triangle with long black pile. Face below the antennae at first convex then very slightly concave to the tubercle which is not prominent; mouth edge retreating, cheeks convex below. Face opalescent yellow, thinly whitish pollinose on the sides, the yellow encroaching somewhat on the frons at the sides. No black stripe over the tubercle but the cheeks in front and narrowly margining the anterior mouth edge, metallic black; behind and across behind the mouth thickly whitish pollinose like the posterior orbits. Antennae chiefly reddish yellow but, in one specimen, considerably darkened on upper part of second and upper half and tip of third segment; short, the third segment considerably broader than its length beyond the tip of second segment; arista two-and-a-half times this length, black.

Mesonotum brilliant shining black, lateral stripes obscurely yellow and with the sides of the thorax pollinose; pile rather long, dusky white.

Scutellum opalescent yellow like the face, the extreme base and corners blackened; pile long, whitish yellow.

Abdomen narrow, with nearly parallel sides, a little widest near the middle of the third segment. The first, fifth and following segments shining metallic; elsewhere opaque black. The second segment with a pair of small, sub-triangular spots about mid-length, separated by a little more than half the length of this segment and distinctly separated from the lateral margins. Third and fourth segments each with a pair of larger, sub-triangular spots situated near, but distinct from, the anterior margin as well as from the lateral margins; at their widest point occupying nearly half the length of the segment; separated by a fourth or fifth the length of their respective segments. Pile of the abdomen abundant, whitish, very long at the base and decreasing regularly in length toward the genitalia. Length of wing 7 mm., exceeding the tip of the abdomen; most of the sub-costal cell infuscated; veins black, anterior cross-vein quite perpendicular. The fore and middle legs chiefly dull yellow, base of femora, coxae and trochanters infuscated; the hind pair chiefly brownish, lighter about the knees, the femora with rather abundant long delicate dusky pile. Squamae, plumulae and halteres whitish, the latter somewhat infuscated.

♀. Eyes bare, face without a black stripe; mesonotum with yellow lateral margins, scutellum with base and anterior corners very narrowly black. Abdominal segments 2 to 5, inclusive, with brilliant, shining, steel-blue bands on the anterior part which are largely occupied by yellow, sub-triangular spots, of which there are four pairs, going over the side margins in their full width but distinctly separated from each other; elsewhere opaque black.

Vertex deep blue-black, shining, continued as a broad, more coppery stripe, evenly of about half the width of the frons, almost to the antennae. The sides of the frons nearly to the vertex, the entire face, cheeks and occiput pale yellow. The sides of the pale frontal stripes, the face (except a pale yellow oval area on the tubercle and the jowls) and the occiput thickly covered with silvery white pollen and with delicate white pile. Pile of vertex and frons black.

Mesonotum brilliant metallic bronze, the lateral margins yellow from the humeri almost to the scutellum, as far as the suture the yellow obscured with white pollen. Pleurae whitish pollinose and with moderately abundant white pile. Scutellum golden yellow, the extreme base and corners black. Pile of the mesonotum dusky, that of the scutellum short, sparse, yellow and black mixed.

First abdominal segment metallic, blue-black the antero-lateral margins broadly yellow. Second segment with an anterior, opaque, black band much attenuated toward, but reaching the extreme lateral margins; at the middle occupying about one-fourth the length of the segment; joining at the middle to a similar opaque band occupying the posterior three-fifths of the segment. Between these two bands an interrupted, metallic, steel-blue band, most of which is occupied with a yellow spot on each side, attenuated mesad and strongly bent forward about the lateral third, not reaching the anterior margin. Third segment with an entire steel-blue anterior cross-band occupying one-third the length of the segment and underlaid with a pair of sub-triangular, yellow spots, which reach the lateral margins in their full width but are distinctly, though narrowly separated from the anterior margin except at the extreme corners. The two spots are separated from each other by more than half their maximum width. Posterior three-fifths of the segment opaque black. Fourth segment similar. Fifth similar to third and fourth except that the posterior band is proportionately narrower and less opaque and the yellow spots only about half as long, reaching the anterior margin on their outer part and even encroaching minutely on the preceding segment. Remaining segments shining blue-black. Venter with a broad, black band on each of the principal segments . Pubescence at base of abdomen moderately long, delicate, whitish; elsewhere short, sparse, colored like the integument.

Fore and middle legs pale yellow except slight infuscation on basal half of femora and at tip of tibiae; hind femur black except broad base and tip, the tibia infuscated on outer part and the hind tarsi much so. Pile of legs whitish. Length 7 mm.

This species approaches the genus *Xanthogramma* but the indistinctness of the yellow on the thoracic margins and pleurae, and especially the slender abdomen with long pile at the base are sufficient to place it in *Syrphus*.

The *types* are in the author's collection. *Cotypes* in the collection of the Maine Agricultural Experiment Station. It should be stated that in these reared specimens the abdomens upon drying have shrunken and curled under so as to present a very different appearance (See Fig. 10, H) from that of the fresh specimens from which Figure 10, C and the description were taken.

PLATYCHIRUS PERPALLIDUS Verrall.

This British species described by Verrall in 1901, and not hitherto recorded from America, has probably been confused with *P. quadratus* Say, to which it is closely allied. The two species may be distinguished as follows:

P. quadratus Say. ♂	*P. perpallidus* Verrall. ♂
Front tibia on the inner side slightly but distinctly concave.	Front tibia on the inner side hardly at all concave or quite straight.
Middle femur with a cluster of long dense pubescence at the base.	*Middle femur entirely without a basal cluster of pubescence.*
The tip of middle femur with a somewhat denser clump of slightly finer hairs.	The tip of middle femur with fewer but heavier hairs.
Middle tibia more flattened and broader; and the first segment of the tarsus somewhat flattened.	Middle tibia less flattened and the first segment of middle tarsus entirely cylindrical.
Last two joints of hind tarsus black; the tip of the front tibia behind is indefinitely infuscated, the only black markings appearing as three or four broken transverse hair lines.	Last two joints of hind tarsus somewhat less blackened and the tip of the front tibia behind with a more distinct black spot.
Abdomen with a distinct median longitudinal black stripe .11 mm. to .17 mm. wide; i. e. roughly one-tenth to one-twelfth the width of the segment thruout segments two to four inclusive; *and a distinct, posterior black crossband of about equal width on each of these segments,* which occupies from one-sixth to one-ninth the length of the segment.	*Abdomen much less distinctly marked with black;* except the first segment and a median anterior triangle on the second segment, *nearly pure orange yellow, the black mid-dorsal line* on segments two to four *nearly or entirely obsolete and the hind margins of these segments very narrowly and inconspicuously black.* The yellow abdomen contrasts strikingly with the brilliant black thorax in a manner suggestive of *Pyrophaena* spp.

The females, as in this entire genus, are distinguished with difficulty. The specimens at hand have the median black line and the black crossbands narrower than in *quadratus*, the abdominal markings more yellow and less reddish than in *quadratus* and the fifth segment with the yellow not interrupted by the median black line and not excised with black behind.

A female of *Platychirus perpallidus,* taken about wild mustard and pea vine on August 3, 1916, deposited about 100 eggs in the laboratory August 4 and 5, which began hatching on August 7; the egg stage occupying about three days. The larvae were fed on *Aphis cornifoliae* Fitch which they took in preference to certain other species offered. They appeared to be full grown by August 21, but did not begin pupation until August 28.

This species was of particular interest because the genus seems not to have been definitely recorded as aphidophagous in the larval stage, although Professor J. W. Folsom[1] suspected from the presence of the adults of *P. quadratus* Say about clover aphids that they might have developed on them.

According to Verrall[2], *P. scutatus,* an European species of the genus, "is said to have been bred from rotten fungi."

I have recently taken males and females of *P. scutatus,* at Orono, about spirea infested with *Aphis spireacola.* The females oviposited in the laboratory and the larvae from these eggs are at the present writing feeding contentedly on these aphids. So that it may be doubted if the larvae of this species developed on rotten fungi.

Egg (Fig. 11, A). The length of a dozen eggs measured, ranged from 1.025 mm. to 1.085 mm., with an average of 1.046 mm.; the maximum width varied from 0.232 mm. to 0.256 mm. with an average of 0.244 mm. *An unusually elongate, straight-sided egg, almost cylindrical and more than four times as long as its greatest diameter,* instead of about three times, as is usual in this group. The sculpturing of the chorion is similar to that of such species as *Syrphus americana, Sphaerophoria cylindrica, Allograpta obliqua,* and others, consisting of irregular elevated bodies surrounded by irregularly radiating elevated arms. There are about forty such elevated bodies the length of the egg, each measuring from 0.025 mm. to 0.045 mm. in length and each surrounded by from 15 to 20 short, thick arms.

In captivity the female deposited the eggs in a somewhat characteristic manner, to some extent similar to that of *Melanostoma mellinum,*[3] three or four being ranked side by side; but also with a strong tendency to place the eggs end to end. As many as four were so placed in a line with the ends contiguous, suggesting very much in their arrangement a string of sausages. (See Fig. 11, A). Whether this same habit prevails in the field I am unable to say.

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[1] Univ. Ill. Agr. Exp. Sta. Bul. 134, 1909.

[2] British Flies, Vol. VIII, p. 263.

[3] Me. Agr. Exp. Sta. Bul. 253, p. 228.

Larva (Fig. 11, C). Length 10 to 11 mm., width at middle 1.75 to 2 mm., height about 1 mm. An elongate, slender-bodied, nearly parallel-sided larva more than five times as long as broad, with moderate transverse wrinkling and gently, irregularly-serrated margins. The color is a beautiful bright tan; the mid-dorsal blood-vessel forms a continuously black line throughout most of the length and is margined on each side with a broad, whitish stripe of adipose tissue, giving off at the sides irregular, slender, curved tongues of similar color which together form another, indefinite, narrow, irregularly curved and broken stripe of white. A third pair of whitish stripes, slender, broken and irregular, lie close to the lateral margins. The integument is finely and evenly papillose but is devoid of integumental vestiture. The segmental spines are light, concolorous and small,—of two segments, the basal one about 0.015 mm. long by 0.022 mm. broad, truncate-cone-shaped, the distal one 0.007 mm. in diameter and about 0.03 mm. long, tapering slightly but blunt at the tip. The anterior larval spiracles (Fig. 11, B) show five minute denticles arranged in a semicircle.

The stigmal plates (Fig. 11, H) are almost sessile, the respiratory tubes which bear them being about 0.18 mm. long by about 0.25 mm. in width by about 0.12 mm. in height. The circular plates or buttons are quite distinct and circular, 0.04 mm. in diameter, and each slit-like spiracle about 0.0375 mm. in length by about 0.0075 mm. in width, but its sides lined with a row of separate minute, rounded denticles which increase the apparent width to 0.015 mm. There are ten to a dozen such denticles along each side of each spiracle. I find no trace of interspiracular ornamentation except a very small rounded nodule, the surface of the stigmal plate appearing quite smooth except for the spiracles. The end of the respiratory organ is decidedly emarginated between the two stigmal plates and the plates turned outward giving the tubes the appearance of being somewhat divergent at their tips.

Puparium (Fig. 11, I, J,). Length 5.5 mm., maximum width 1.85 mm., maximum height 1.75 mm. The colors of the larvae are at first carried over into the pupa stage but are gradually transformed to a more uniform reddish brown although the black and white stripes of the mid-dorsum persist for a longer time. The integument becomes fairly smooth, much indurated and glazed.

The puparium is moderately inflated, globose in front, broadest about the anterior third thence somewhat irregularly and gradually attenuated to the posterior end. In side view (Fig. 11, I) the ventral line is seen to be gently convex, the dorsal line arising nearly perpendicularly from it, but soon rounding away to its maximum height about the anterior third. Thence it descends with a moderate hump over the posterior third to the posterior respiratory organ which is terminal.

Adult (Fig. 11, D, E, F, G). I quote in full Verrall's original description:[1]

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[1] British Flies, Vol. VIII, pp. 290-292.

"*P. perpallidus* n. sp. Face scarcely at all produced; front tibiae of the male gradually dilating from base to tip, front femora with moderate pale pubescence behind; abdomen and legs nearly all orange in both sexes.

"♂. Face and frons obscured by yellowish grey dust, which leaves only the central knob, the front mouth-edge, and the space above the antennae shining black; the hairs on the face are fairly abundant, rather short and mostly pale, but on the frons they are longer and partly black; the space before the jowls is blackish; the jowls themselves and the back of the head are yellowish grey, but more aenous towards the occiput; the pubescence on these is luteous, becoming longer on the upper part, and nearly all black on the raised shining aenous black vertex. Antennae entirely brownish black; arista dark orange to blackish, about as long as the antennae.

"Thorax and scutellum intensely shining aenous with rather abundant mostly equal tawny pubescence, which is however longer round the scutellum, and longer and more shaggy on the back part of the mesopleurae; there are a few black hairs about the lowest part of the sternopleurae.

"Abdomen all orange or tawny except at the black base which converges about the middle of the second segment to a narrow dorsal line which extends to the end of the fourth segment, while the hind-margins of the second, third, fourth, and fifth segments are very narrowly and inconspicuously blackish (but not quite so narrowly in the specimen from Kingussie). Pubescence nearly all yellow, and as usual longest about the basal corners; belly all orange. Genitalia small, mostly shining aeneous black.

"Legs all orange except on the black coxae and trochanters, while the hind tarsi are partly brownish on the moderately dilated basal joint and less distinctly so on the two last joints; the hind femora and tibiae bear a blackish ring about the middle in the specimen from Kingussie, and there are faint traces of such ring in the Sutton Park specimens. Front tibiae slowly and gradually dilated from soon after the base to the tip, which is the widest part; this tip is rather whitened and is a little obscured; the front tarsi are not so much widened as the tip of the tibiae and they very gradually diminish in width, being dilated even up to the tip; the basal joint is longer than the next two and more than twice as long as the second joint. The *pubescence behind the front femora* is moderate and is *all yellow* and inconspicuous, the long woolly white hair at the base behind being present as usual in this group; the front tibiae bear a slight fringe behind about the middle. Middle trochanters bearing some strong black bristles, while the middle femora bear a moderate pubescence which is nearly all yellow and amongst which are no small black bristles, but towards the front at the tip almost beneath are about five unusually long recurrent hairs, which form a peculiar distinctive character for this species; the tibiae are slightly dilated about the middle and bear a long dense fringe in front almost beneath and a slighter fringe behind; hind tibiae without any fringe; the tiny bristles on the legs are all yellow.

"Wings considerably brownish, but rather tawny about the base and the stigma. Squamae and their fringes brownish yellow. Halteres orange.

"♀. Rather similar, but even the hind tarsi are almost all orange being only a little discolored above the base of the basal joint; the second, third, and fourth abdominal segments have black hind-margins which occupy about one-fifth of each segment, and the inner hind corners of the orange spots are more rounded than in the male, but less than in the female of *P. fulviventris.* Frons broad, being at the vertex about one-third the width of the head; it is shining blue-black there, but the side dust spots are so large as to leave only an indistinct middle line connecting to the indistinct shining black space above the antennae; the pubescence on the upper half of the frons is partly black.

"Length about 8 mm."

This species is much commoner in Maine than *P. quadratus,* being represented in the collections by about 50 males and an equal number of females. Especial abundance was noted at Orono the tenth and eleventh of August, 1915 and the thirteenth to the eighteenth of June, 1917. Other dates for Orono are July 31, Aug. 1, 6, 12, 15, 16, 19, and 25. Specimens were also taken at Fort Kent, July 5 and 6, Presque Isle, July 8, and Bar Harbor, July 25.

The adults are commonest in tall grass, seeming to show a preference for the proximity of open ditches where they hover about, alighting frequently on the grass blades or spikes, males as well as females teetering up and down with the abdomen as though about to oviposit. Examination of these sites has so far not revealed any other stage of the insect.

SYRPHUS KNABI Shannon.

(*Syrphus xanthostomus* Willist. of Metcalf in Ohio Nat., Vol. XIII, No. 5, pp. 81-83.)

In the Ohio Naturalist for March, 1913, I published a description of what was called the Pemphigus-Gall Syrphus-Fly, under the name of *Syrphus xanthostomus* Williston.

I was aware at the time that Williston's rather brief description did not fully cover the adults under observation, particularly in regard to the distinctly yellowish lateral margins of the thorax and the absence of the median, narrow, deep, emargination in the posterior margin of the second and third yellow abdominal bands. However as Williston's type was not examined, certain points of discrepancy were simply incorporated in the description of the adult and no new name created for the species discussed.

Mr. R. C. Shannon[1] has recognized and recently described this species as distinct from *xanthostomus,* under the name of *Syrphus knabi.* The Ohio specimens from Pemphigus galls agree quite closely with Shannon's description. The "Pemphigus-Gall Syrphus-Fly" therefore should be called *Syrphus knabi* and not *Syrphus xanthostomus. Syrphus knabi* has also been reared in Maine from the pseudo-galls formed of ash leaves by *Prociphilus fraxinifolii* Fitch. The galls of *Pemphigus oestlundi* Cockerell *(P. vagabundus* of authors) have never been recorded from Maine.

The metamorphoses of *Syrphus xanthostomus* Williston are also under observation at the present time; and, if there were any possible room for doubt as to the specific separation of these two species from examination of the adult alone, the immature stages and biology show them to be abundantly distinct.

These larvae were first taken in Maine on July 7, 1915, exactly the date on which, four years previously, they were found in the Pemphigus galls in Ohio. Additional specimens were collected July 16 and 21 and again on July 18, 1917. The larvae, at least when nearly full grown, are found in the rather tightly-curled parts of the leaves surrounded by numbers of empty skins of the aphids, an eloquent witness to their ravages during growth. In such situations they are only slightly less protected than in the Pemphigus galls.

The Pemphigus-gall larvae were described as follows:

"*Larva.* Length about 10 mm. (8 to 11.5), width 3.75 to 4 mm., height 2.5 to 3 mm. Fat, thick, grub-like, sluggish larvae, elongate oviform in outline, strongly arched dorsally (Fig. 12, B). Wrinkles prominent, produced laterally into an irregular, dorso-lateral carina; the ventral folds of the body in the principal segments serve as very imperfect prolegs. General color very pale, pinkish-yellow. Heart line not conspicuous. Skin bare, the segmental bristles short and light in color, very inconspicuous." About 0.07 mm. long, of the usual two segments, the basal one about 0.23 mm. in diameter by a little longer, the distal one less than half as broad at the base and accuminate.

"The jaws of the mouth-parts are unusually short, their width at base equal to their length, the lower jaw the heavier. Mouth-hooklets apparently three pairs: two near the jaws of which the ventral pair is the heavier, the third pair lateral in position, heaviest of all. There are a number of sensory papillae around the mouth-parts and antennae. The antennae are small, situated close together above the jaws, of the usual form (see Fig 12, A).

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[1] Proceedings of the Biological Society of Washington Vol. XXIX, p. 200, Sept. 22, 1916.

"The prothoracic spiracles are slightly elevated, blunt, short, horn-shaped as seen from the side (Fig. 12, A, g), the semi-circular slit apparently guarded by six, blunt teeth, one of the median ones emarginate or imperfectly divided (Fig. 12, C). The posterior respiratory appendage (Fig. 12, D, E) is" a little "longer than broad, testaceous brown, ringed about mid-length, thence slightly constricted. The spiracles (*a*) moderately long, somewhat elevated above the surface; the inter-spiracular spines (*b*) short" sharp ridge-like, "rather prominent. Dorsal spiracular spine (*c*) short compressed; its breadth about equal to diameter of the approximate circular plate (*d*).

"These larvae were found, full-grown, at Cedar Point, July 7, 1911. The larval stage continued indoors to July 11 and 12.

"They were collected on the Poplar or American Aspen (*Populus tremuloides Mx.*) in the well-known, characteristic galls on the ends of the twigs, made by the aphid, *Pemphigus" oestlundi* Cockerell.

The larvae taken from the Ash pseudo-galls, in correlation with the greater freedom of motion afforded them all during development, did not present such exceptional height and thickness. While unusually corpulent, they retained the typical *Syrphus* shape, as in *torvus* for example, and were less sluggish than those described above.

The length of the full grown larvae when extended exceeded 17 mm., their greatest width fully 4 mm. and their height about 2.5 mm. Cross-section semi-circular. The ground color of these larvae (the body fluids showing through the integument) is a dull ashy gray with areas of orange and black where viscera of these colors showed faintly. The ashy gray is overlaid extensively with ashy white adipose masses in the usual position; beginning at the anterior end with a narrow, mid-dorsal line which widens wedge-shaped caudad until in the posterior half of the body it occupies most of the width of the body. It is interrupted at each segment by a prominent emargination at each side and by an elongate, pulsating area on the middle line. The posterior respiratory organ is a warm brown in contrast with the whitish body.

While the respiratory tube is not elongate, the stigmal plates are noticeably more elevated than in *Syrphus torvus, ribesii,* etc. *The respiratory organ in knabi is at least as long as its width at the tip; in that of torvus the length does not exceed two-thirds the width.* The length of the tube is from 0.53 to 0.61 mm., its width from 0.49 to 0.57 mm., with an average of 0.525 mm. and its height 0.31 to 0.335 mm., average 0.325 mm. The transverse diameter of the circular plate is about 0.06 mm. its dorso-ventral diameter about 0.09 mm.; the inner margins of the two about 0.129 mm. distant. The median spiracle measures about 0.16 mm. in a straight line, its width about 0.012 mm.

The surface of the respiratory tube is only indistinctly and irregularly papillose, polished; with shallow grooves along the median line, dorsad and ventrad, which meet across the tip in a moderate emargination between the two stigmal plates which are only a very little divergent.

The slit-like spiracles are a little elevated on carinae, are almost exactly straight in surface view, and about equi-distant and equally divergent from each other.

The interspiracular ornamentation consists of short, sharp, elevated irregular ridges, or carinae, (*instead of nodules*), much more elevated than the spiracles; hardly at all continued down the sides of the tube; pale brown in the larva, black during the pupal stage.

Puparium (Fig. 12, F, G). Average length 7.2 mm., height 3.5 mm., width 3.8 mm.

"These puparia (Fig. 12, G) are exceptionally inflated dorsally, the ratio of height to length being greater than in any of the other species I have examined. It is characteristic of them also that the posterior inflation is equal to, or greater than, that anteriorly; in outline, as seen from the side, the dorsal half of the puparium makes an almost perfect semi-circle," reaching its greatest height a little in front of the middle. "The ventral line is sinuate. The respiratory appendage (*a*) projects from the lower posterior part. From above, the outline is sub-ovoid, broadest in front of the middle, thence narrowing gradually to the posterior third; whence the puparium is strongly and unevenly compressed to the tip of the respiratory appendage.

"Color at first grayish brown, sometimes marked with oblique patches of black; posterior breathing appendage darker. As the pupa approaches metamorphosis the anterior end darkens to deep reddish-brown in the region of the eyes; while on the posterior half, the three principal, yellow abdominal bands of the adult become visible through the transparent wall." Color of the empty puparium light testaceous brown.

"The segmental spines remain, as in the larva, very inconspicuous. The posterior breathing appendage also retains its characteristics."

The larvae from Ash developed as follows:

One pupated	July 16th,		
One "	July 19th,	emerged	July 30.
Two "	July 20th,	"	July 30.
Three "	July 24th,	"	Aug. 1.

The duration in this stage under laboratory conditions was therefore from eight to eleven days. The pupation record for the Ohio specimens was seven to eight days.

Adult (Fig. 12, H, I). Shannon's description is as follows:

"Squamae with rather long, light yellow pile; ground color of the sides of thorax bright yellow, with yellow pile; bands on the third and fourth abdominal segments entire and extending over the margins almost in their full width.

"Male: Frons yellow with bluish green reflection, a black spot above each antenna, and with fine rather long, black hairs which continue a short distance down between the antennae and eyes. First two antennal joints reddish-brown, the third joint darker, reddish beneath and somewhat pointed apically (See Fig. 12, J); arista brownish, a little longer than antenna. Face and cheeks yellow and with light pile. Mesonotum greenish aeneous with two obvious median stripes and bright yellow sides clothed with light golden pile; pleurae a somewhat lighter yellow than the lateral stripes of dorsum, and with golden pile; scutellum yellow with a greenish sheen and with black pile, the sides with yellow pile. Band on the second abdominal segment interrupted and outwardly produced forward where it extends over the sides and up onto the sides of the first segment. The bands on the third and fourth segments run straight across, extending over the sides in almost their full width. Fore coxae and trochanters cinereous, the hind trochanters yellowish, front and middle legs entirely yellow; hind pair yellow, the femora with dark band beyond the middle, yellow posteriorly; hind tibiae darkened on outer side of apical half and clothed with black pile; last four tarsal joints darkened. Length about 11.5 mm.; wing about 11 mm.

"Female: Width of frons at vertex about equal to length of third antennal joint, but widening quite rapidly down to the antennae. Frons yellow, brightly so for about one-fourth its extent above antennae above this a region with a greenish-black reflection which has an ill-defined triangular mark; the last section, which includes the ocelli, is nearly as long as broad and is shining black; a black spot above each antenna.

"This species.......................has been confused with *ribesii, grossulariae, and xanthostomus.* It differs from *ribesii* and *rectus* in its bright yellow mesonotal side margins; apically pointed third antennal joint; bases of femora in male yellow, and second and third yellow bands of abdomen but little narrowed laterally........................the small bristles on the under side of the middle tarsi yellow instead of black."

EXPLANATION OF FIGURE 8.

Immature stages of *Xanthogramma divisa* Willist.

A. Eggs of *Xanthogramma divisa*, the two above in dorsal view, the one below in side view, X 40.
B. Characteristic sculpturing of the shell of the egg as it appears at a magnification of 300 diameters.
C. Dorsal view of larva just after hatching, X 50.
D. View of full-grown larva from the caudal aspect, X 8, to show its unusual flatness.
E. End view of the posterior respiratory organ of the larva, X 115, showing circular plates, slit-like spiracles, and the irregularly-rugose inter-spiracular ridges.
F. Dorsal view of the larva, X 5, to show color pattern.
G. Dorsal view of the posterior respiratory organ, X 40.
H. A part of the marginal serrations of the larva more enlarged, showing the three large and one smaller serration occurring to each segment and the minute, integumental papillae.
I. Dorsal view of the puparium, X 8, showing shape and color markings.
J. Outline drawing of the puparium, X 8, showing shape from the side.

For other figures of *Xanthogramma divisa,* see 9 and 12 K.

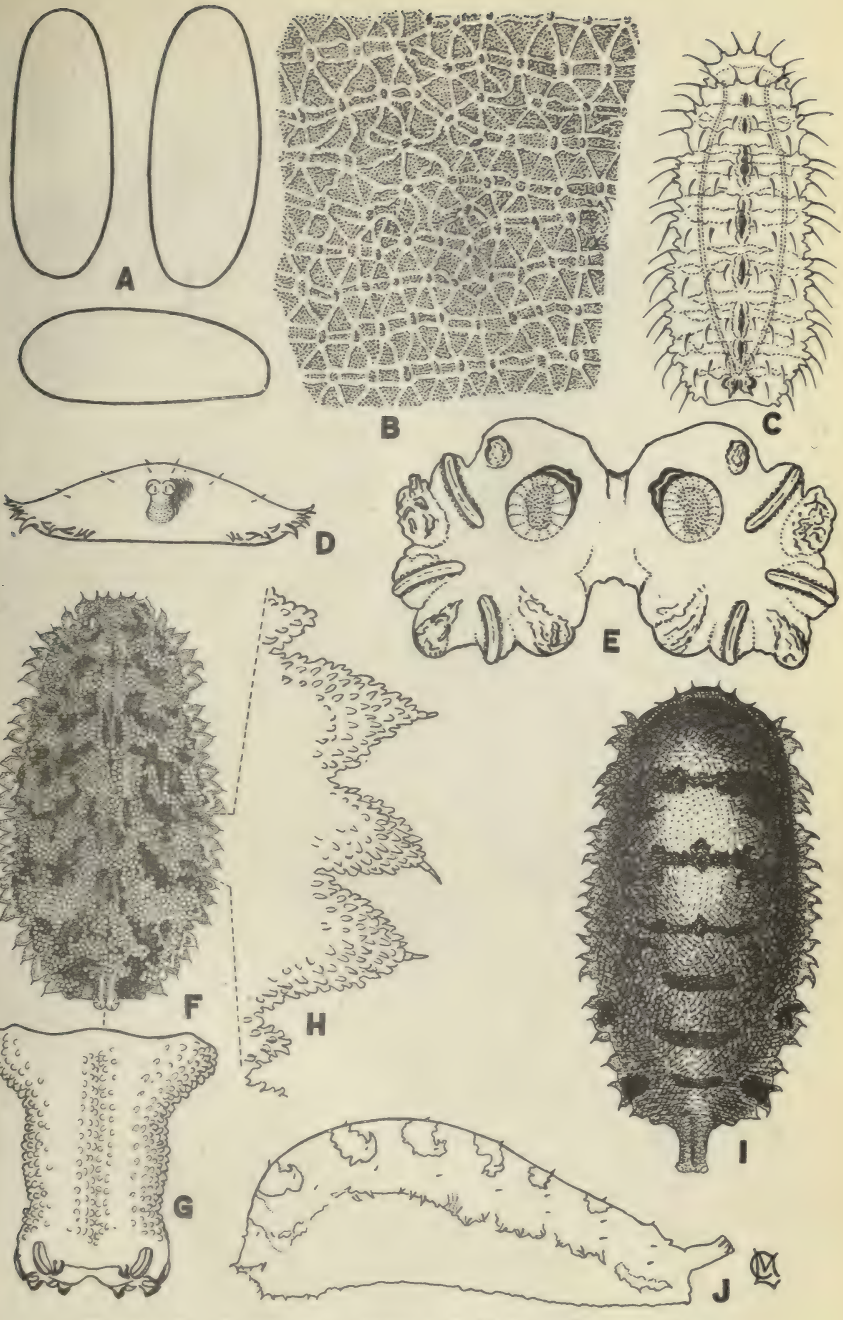

Figure 8. Immature stages of *Xanthogramma divisa.*

EXPLANATION OF FIGURE 9.

Life stages of *Xanthogramma divisa* Willist.

From photographs by R. L. Hammond; enlarged two diameters.

A. Larvae taken under loose bark of a willow tree in Autumn.

B. Puparia; the three above, found under loose bark and on the ground under the same tree in June. The one above the letter B shows an emergence hole from which 26 parasites (species undetermined) issued July 8. The one immediately below the letter B is an empty puparium from which the adult has emerged. The larval mouthparts may be seen as an anterior, ventral, black V.

C. Adult females reared from the larvae.

See also figures 8 and 12, K.

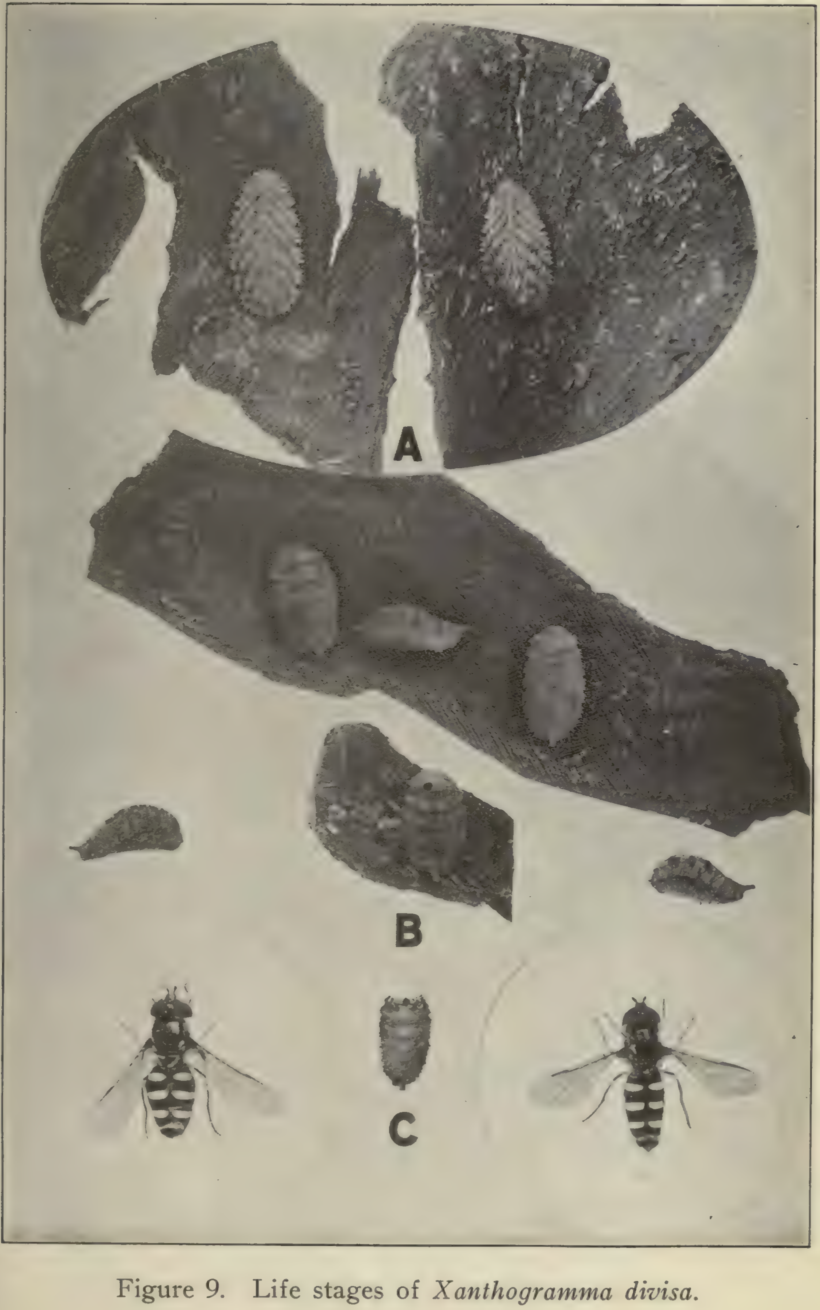

Figure 9. Life stages of *Xanthogramma divisa*.

EXPLANATION OF FIGURE 10.

Life stages of *Syrphus oronoensis* n. sp.

A. Dorsal view of larva to show color pattern; X 7.
B. Dorsal view of the puparium, X 8, showing shape and color pattern.
C. Adult male, X 9 (legs and right wing omitted). The abdomen is here shown as it appears during life (cf. fig. 10, H).
D. Posterior respiratory organ of the larva, dorsal view, X 40.
E. Posterior respiratory organ from the side, X 40. Note the characteristic constriction two-thirds the way from the base.
F. End view of the posterior respiratory organ X 170, showing median dorsal spiracular ridge, the irregular shape of the button or circular plate, the slit-like spiracles, and the minute inter-spiracular spines.
G. Puparium from the side, X 8.
H. Abdomen of the type male, X 6, as it appears after drying and shrinking.

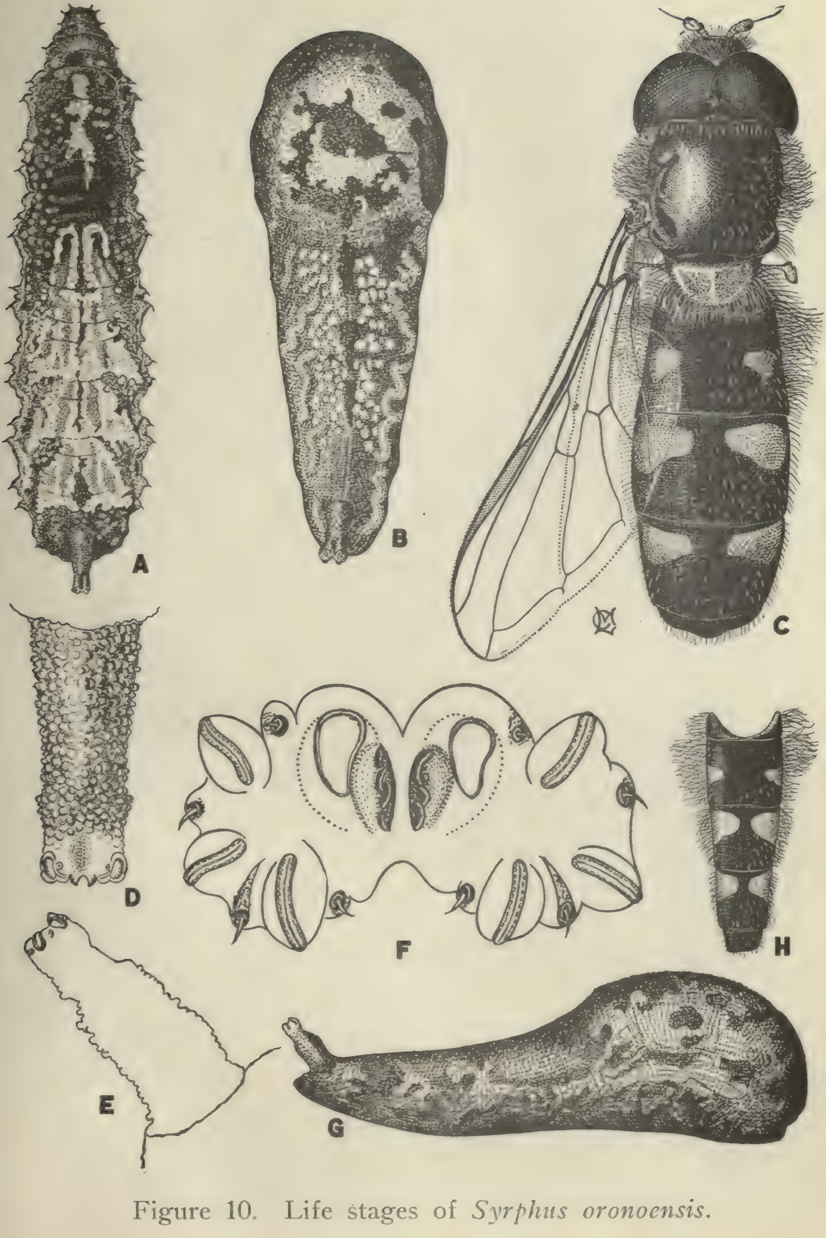

Figure 10. Life stages of *Syrphus oronoensis*.

EXPLANATION OF FIGURE 11.

Life-stages of *Platychirus perpallidus* Verrall.

A. Three groups of eggs as placed by female in captivity, X 17.
B. Two views of the anterior larval spiracle, highly magnified.
C. Dorsal view of full-grown larva, X 8.5.
D. Front femur, tibia and tarsus of male, redrawn from Verrall on comparison of specimens.
E. Middle leg of male, redrawn from Verrall on comparison of specimens.
F. Part of thorax and abdomen of the female, X 10.
G. Part of the thorax and abdomen of the male, X 10.
H. End view of posterior, larval respiratory organ, showing circular plates, stigmal plates, slit-like spiracles and inter-spiracular nodules, X 300.
I. Outline to show shape of the puparium from the side, X 10.
J. Dorsal view of the puparium, X 10.

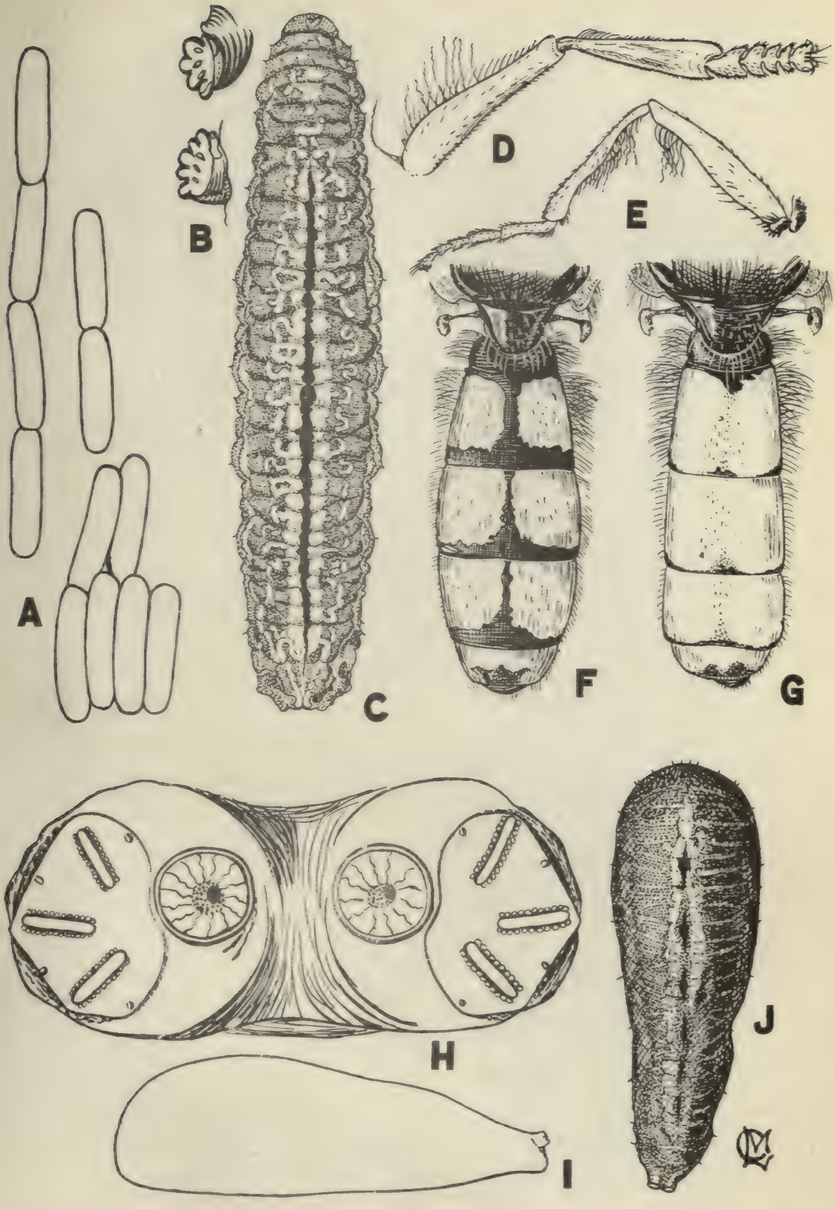

Figure 11. Life stages of *Platychirus perpallidus*.

EXPLANATION OF FIGURE 12.

A to J, inclusive, life stages of *Syrphus knabi* Shannon.

A. Antero-ventral view of head of larva much enlarged; *a,* sensory papillae; *b,* antenna; *c,* upper jaw; *d,* outer pair of mouth-hooks; *e,* other mouth hooklets; *f,* lower jaw; *g,* anterior spiracles or larval respiratory cornua; *h,* cephalo-pharyngeal framework within the body.

B. Lateral view of larva, X6; *a,* median segmental spines; *b,* posterior respiratory organ.

C. End view of anterior spiracle, highly magnified.

D. Dorsal view of posterior respiratory organ, X 40; *a,* one of the three pairs of slit-like spiracles; *b,* one of the inter-spiracular ridges; *c,* the median dorsal spiracular spur; *d,* the circular plate.

E. End view of the posterior respiratory organ, X 40. Lettering as in D.

F. Outline of the puparium, dorsal view, X 3; *a,* posterior respiratory organ.

G. Outline of the puparium from the side, X 3.

H. Scutellum and abdomen of adult ♀, X 5.

I. Wing, X 5.

J. Antenna of male.

(Figures A to I redrawn from the Ohio Naturalist).

K. Abdomen of *Xanthogramma divisa,* X 10, to show arrangement of the yellow markings.

For other figures of *Xanthogramma divisa,* see figures 8 and 9.

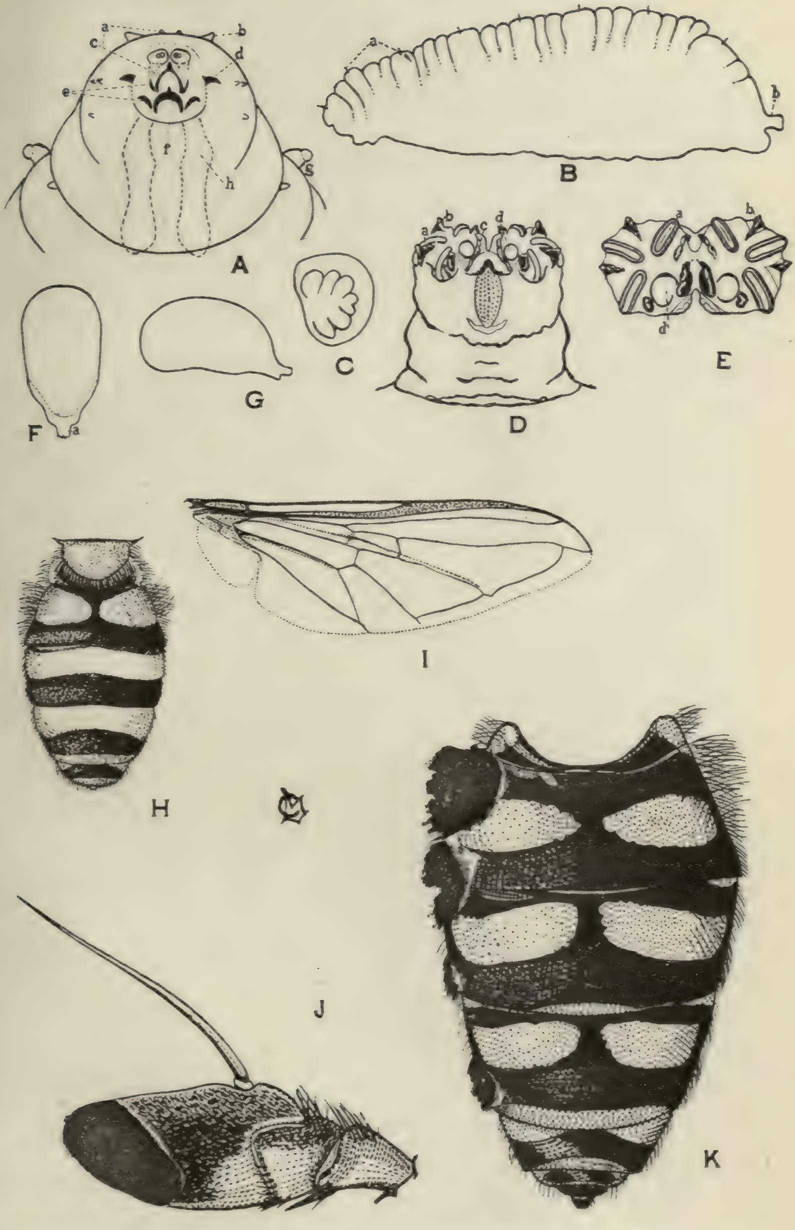

Figure 12. Life stages of *Syrphus knabi; K,* abdomen of *Xanthogramma divisa.*

Kentucky
Agricultural Experiment Station

University of Kentucky, Lexington, Kentucky

A. M. PETER, Acting Director

CIRCULAR NO. 15

HOUSEHOLD PESTS AND THEIR TREATMENT

BY

H. GARMAN

COMMONWEALTH OF KENTUCKY

June, 1917

CIRCULAR NO. 15.

HOUSEHOLD PESTS AND THEIR TREATMENT.

By H. Garman,
Entomologist and Botanist.

Inquiries coming to the Department from time to time with reference to treating household insects, together with the growing recognition among people generally of their importance from the point of view of health and happiness have seemed to me to render desirable an account of the common pests of this sort, somewhat more complete than can be given in correspondence. Malaria, typhoid fever, typhus, plague, yellow fever, spotted fever, filariasis, and Asiatic cholera, constitute an impressive list of human diseases now definitely traced to insect carriers, yet it is far from complete and each year makes additions to the number of ailments conveyed by one or another insect. In view of what has already been accomplished in the way of preventing these diseases as a result of this knowledge it may fairly be said, I think, that the greatest advance in medical and sanitary science made in recent years is a result of the discovery of the relation between insects and diseases. But a great boon remains to be conferred upon mankind by teaching the facts learned, repeating and re-repeating them, until the most ignorant and thoughtless among us, those who suffer most, are impressed with the importance of guarding their homes against such dangers.

ANTS.

Every year complaints are received by me from people who are worried by the activities of these persistent little animals, colonies of which have taken up their domicile in some dwelling and refused to be driven out by any ordinary treatment known to the housekeeper. They get into sugar bowls, upon cakes and other pastry, into sirup, and, in fact, almost anything edible. They are thus likely to be brought to the table, to the great mortification of those who take pride in neat housekeeping. For it is no reflection upon anyone's carefulness that these persistent creatures now and then invade a dwelling and refuse to be routed out. Two different species seem to occasion most of the complaints, tho others at times appear about houses. The smaller of the two (*Monomorium minimum*) is a dusky or blackish species which lives outside buildings, sometimes under the bricks of walks, and comes into and goes out of houses by chosen routes, pretty constantly adhered to. The individuals commonly seen are all wingless workers, which have duties in the colony similar to those of worker bees. They do the foraging and take care of the young. When the colony is exposed, there will generally be found among the workers a large ant, the fertile mother of the colony, whose duties are exactly those of the queen bee, namely, the laying of eggs and the production of new members of the colony. At certain times, generally early spring, most such insects produce small winged males, which soon die after mating with winged females, which then return to the earth to found new colonies after discarding their wings. These simple facts will make clear the reason why a thoro destruction of the nest and queen of the little marauders will more certainly put a stop to their depredations than anything else that can be done.

A second house-infesting ant (*Monomorium pharaonis*) is commonly known as the red ant, tho yellow in color. It is an introduced species and seems to be more completely adapted to a life in dwellings than its smaller dusky relative. It makes its home between floors in walls and seems to be, like the bedbug, an associate and parasite of man. Because of its nesting habits it is more difficult to get rid of than the small black species, and often housekeepers despair of suppressing it entirely after expending, as they claim, all their ingenuity, and after testing all the suggestions made by economic entomologists. Its life-history is much like that of the related insect, and it is certain that once its laying queen is destroyed and the nest broken up, the colony will soon scatter and perish. It may well be worth while, therefore, to take the pains necessary to locate the nest, even at the expense of taking up flooring or breaking into walls. In some cases it is not actually necessary to do this. The nests may be reached by steam, by oils, or by fumes of some sort, so as to destroy all of the occupants. Until this is done, however, other treatment must be considered only palliative and of temporary value.

Insect powder should be strewn about shelves and floors at frequent intervals when the ants are about. If persisted in this alone can be made to suppress them. But the brown color of this powder stains fabrics and may be considered on this account objectionable, tho the stain is not permanent. Coal-oil, whenever its use is practicable, is the most effective insecticide known. If it can be sprinkled across the routes taken by the ants it is a barrier across which they dare not pass. A touch of the oil to their bodies is fatal, sooner or later. Benzine is a more volatile oil sometimes used in preference because it soon evaporates, leaving no trace behind. This quality has disadvantages as well as advantages, since it does not long remain effective and destroys only the ants it comes in contact with immediately after it is used. Coal-oil, on the contrary, remains effective longer, tho gradually disappearing, leaving, however, traces that in some situations may be objectionable. A bath sponge that has been made to absorb a sirupy preparation makes a good trap when exposed in a saucer. It may, from time to time, as it becomes covered with ants, be dropped into hot water. A tin tray covered with grease is an attractive bait for yellow ants, and can be burned off over a gas jet, or coal fire, to destroy them.

Ant tapes, so-called, consisting of strips of cotton cloth or of cotton tape treated with substances offensive to ants have been found very useful as a means of keeping ants from ascending the legs of tables, sideboards and the like. Turpentine, coal-oil and oil of citronella are effective on these tapes and can be used with safety in almost any part of a dwelling. Turpentine soon evaporates and must be renewed. Its odor, also, is objectionable to many people; of the three, perhaps oil of citronella is to be preferred. A very effective tape can be made by soaking cloth, or tape, in a solution of corrosive sublimate, as follows: Dissolve by boiling in a porcelain dish or glass beaker a small quantity of corrosive sublimate in four or five ounces of water. When cool, filter thru good filter paper, then soak the tape for four hours and finally suspend it in loops from a cord stretched across the room until dry. It has no perceptible odor, and strips tied about objects will last for months. The fluid and cloth are poisonous, so must be handled at all times with caution, the tape to be finally burned. The substance is corrosive to metals also, and must not be brought in contact with them for any length of time. Scissors used to cut the tape should be washed carefully, as should the hands.

Sometimes one, sometimes another of these precautions becomes practicable, according to circumstances. And again several may be employed to advantage at the same time. But it should always be remembered that the complete suppression of these pests can be most quickly accomplished by finding and destroying the nests, whether indoors or out.

HOUSE-FLIES.

The only fly very troublesome about dwellings and calculated to do us serious harm is the common *Musca domestica,* a species that appears to have followed man in his peregrinations about the globe and in spite of his hostility to have persistently held its own as an occupant of his habitations.

The house-fly passes the early stages of its existence in manure and other decaying vegetable substances. The eggs are placed there by the adults and produce maggots in a few days. These feed on the refuse and soon become enclosed in a firm, brown coat in which they assume the quiescent pupa stage, after which they come forth as adults. The whole life-story of a fly may be completed in eight days, during very warm weather, but varies with the temperature. The winter is passed in the adult, or partly in the pupa stage. Flies which have passed the winter hidden away about dwellings place eggs in manure in May, and a succession of generations develops during the summer months. These simple facts are very well known to many people now,

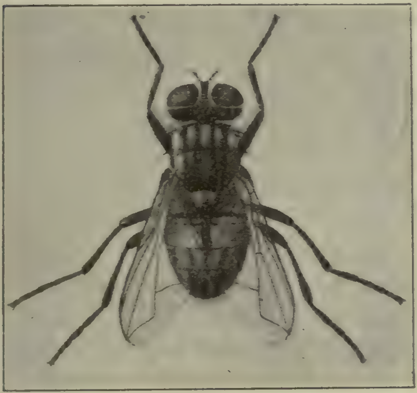

FIG. 1. The common house-fly (*Musca domestica*) adult. Original.

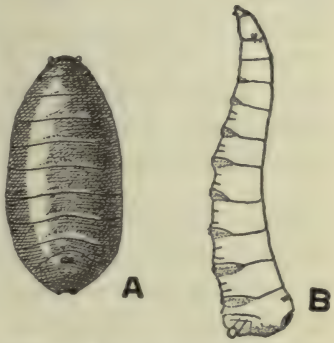

FIG. 2. The common house-fly. A, pupa; B, larva. After Howard.

and explain why boards of health insist on frequent cleansing and disinfecting of stables about cities. This is, in fact, the most important precaution to be taken in dealing with the

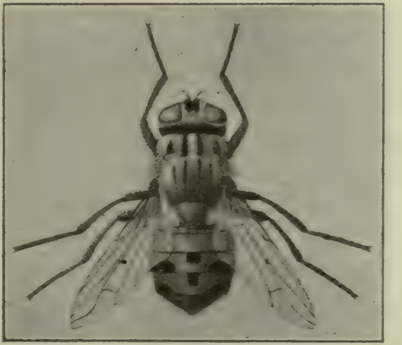

FIG. 3. The stable-fly (*Stomoxys calcitrans*). A stinging species sometimes entering houses. Adult. Original.

house-fly. If all stables could be abolished within city limits it would go a long way toward reducing the trouble experienced in keeping flies from city dwellings. A single stable in the neighborhood is often the source of nine-tenths of the flies found in houses in the vicinity. A sudden reduction in the numbers of flies in a household has more than once been observed following the removal of a stable from the vicinity. Very often people rear on their premises most of the flies that appear in their kitchens. The question of getting rid of flies thus often resolves itself into getting rid of their breeding places. Vegetable litter of any sort in damp places should always be removed either by hauling it away and using it for the improvement of soil, or by burning it, tho this should be avoided if practicable. When it is not possible to remove accumulations as promptly as desirable, they should be treated in such a way as to keep flies from breeding in them. Darkened bins of cement, screened bins, or bins with fly-tight wooden lids, are sometimes used for this purpose, while various substances such as formalin, cresol, powdered borax, lime chlorid, a solution of powdered hellebore, and the like, have been recommended for the treatment of manure to destroy the eggs and maggots. Probably borax, one and a fourth pounds to eight bushels of manure, as recommended by F. C. Cook, is as effective as any of those tried.

Every careful householder should use his influence toward having ordinances enacted providing for systematic inspection of all stables, and a strict enforcement of provisions for the cleansing and disinfecting of all breeding places for flies. With these precautions looked after at all times, the housekeeper will have much less difficulty in controlling the pest within doors. Yet sticky fly paper, wire gauze traps, and screens on doors and windows, cannot be entirely dispensed with during the summer months.

When flies by some chance have entered a kitchen in large numbers, insect powder can be made to destroy them quickly, the usual procedure being to puff the powder from a bellows into the room in the evening and closing the door. In the morning the killed and disabled flies can be swept up and burned

Disappointment in the use of this powder is sometimes the result of buying powder that has lost its "strength" from not having been kept in tightly closed receptacles.

MOSQUITOES.

Mosquitoes are to be considered very dangerous household pests, tho they commonly breed out of doors. Some species, such as the yellow fever mosquito, may be said to live, when adult, in dwellings, for they seem never, at this latitude, to be found in the woods and fields. Others, like the malaria mosquito, breed in streams and ponds and enter houses less frequently when adult.

The yellow fever mosquito is constantly present in Kentucky, becoming most common in late summer, when, at times, it is so numerous as to occasion much suffering, tho not ordinarily conveying yellow fever, because the disease is not present in the State except when brought here by people coming from infected regions farther south. The mosquito is by far the worst house-infesting species, and is quite capable of giving rise to an epidemic of the fever here, as it did in 1878, at Hickman, when 749 cases and 149 deaths occurred, if the conditions are ever allowed to become favorable. A single yellow fever refugee, not quarantined, is calculated to supply the conditions.

The yellow fever mosquito (*Aedes calopus*) breeds almost or quite exclusively in barrels and buckets about dwellings. In Kentucky it is not found elsewhere, and people who suffer from the pest often furnish the breeding places. A single bucket partly filled with water and left standing near the kitchen door will provide enough of the insects to render miserable the lives of everybody in the immediate neighborhood.

The adult mosquito can be recognized by its sharply black-and-white banded legs and the silvery dots and lines on its body. It is active during cloudy days, coming out from behind desks and other hiding places and alighting quietly on the wrists and ankles of people who are closely occupied at a desk or in reading, and darting away again and hiding whenever any

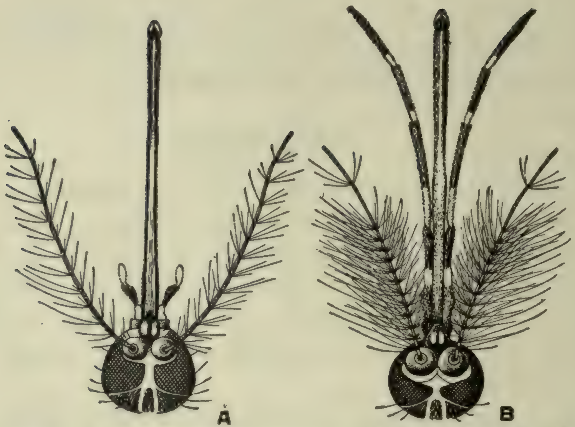

FIG. 4. Heads of yellow fever mosquito (*Aedes calopus*). A, female; B, male. Original.

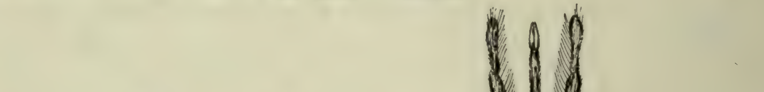

FIG. 5. Heads of malaria mosquito (*Anopheles punctipennis*) A, female; B, male. Original.

threatening demonstration is made by its prey. It appears to cease biting when complete darkness comes on.

The common brown mosquito (*Culex quinquefasciatus*) also breeds in buckets and barrels, but is not so closely restricted

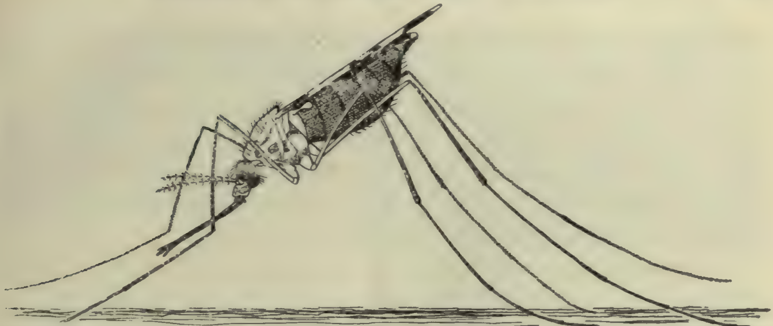

FIG. 6. Side view of resting malaria mosquito (*A. punctipennis*). Female. Original.

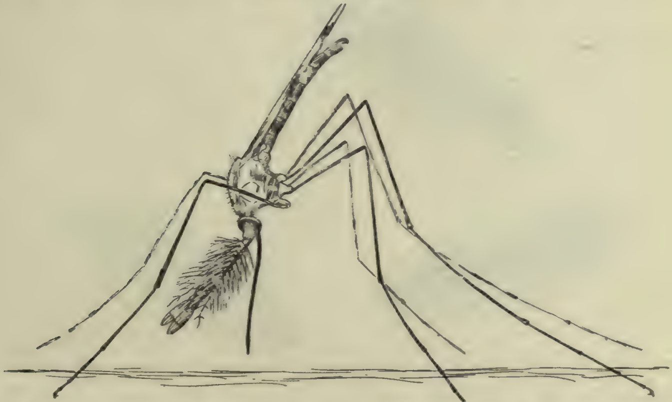

FIG. 7. Side view of resting malaria mosquito (*A. punctipennis*). Male. Original.

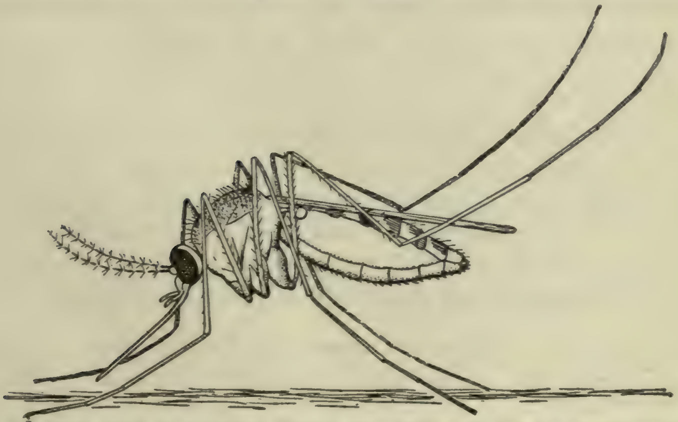

FIG. 8. Side view of common brown mosquito (*Culex quinquefasciatus*) Female. Original.

to them as is the yellow fever mosquito, being often found both as a larva and as an adult at a distance from dwellings. Its legs are not distinctly banded, and it lacks silvery markings. It is not as persistent a biter as the other, and cannot be said to be a very serious pest in most Kentucky households. Yet it is charged with carrying filariasis and some other diseases, and should be kept suppressed wherever practicable.

Two mosquitoes belonging to the genus Anopheles are to be found in dwellings in Kentucky, both to be recognized by their habit of holding the body at an angle with the surface on which they rest. The commonest one is readily recognized by its mottled wings, these organs being conspicuously marked with black and brown. It is a rather large insect, tho it is not known to convey malaria. It passes the winter as an adult in caves and cellars.

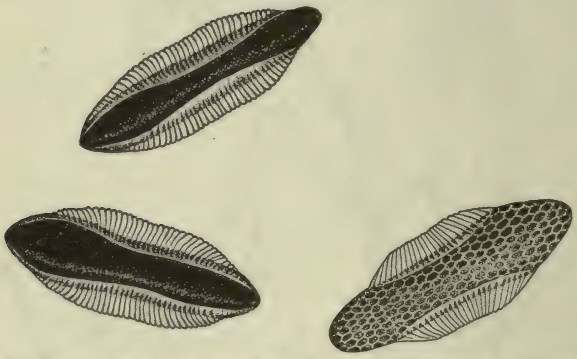

Fig. 9. Eggs of malaria mosquito (*A. punctipennis*). Original

The mosquito (*Anopheles maculipennis*)[*] really carrying malaria is also not rare as a visitor to households. It is somewhat smaller than *A. punctipennis,* and is not conspicuously marked, but can generally be recognized among our species by the position which the adult assumes when at rest. Its young are found in spring-fed ponds and in recesses along the shores

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[*] Theobald, the British writer on mosquitoes, has been followed in using this name, and with the knowledge that Howard and Dyar have recently questioned its validity as applied to our species, suggesting instead the name *Anopheles guttulatus.*

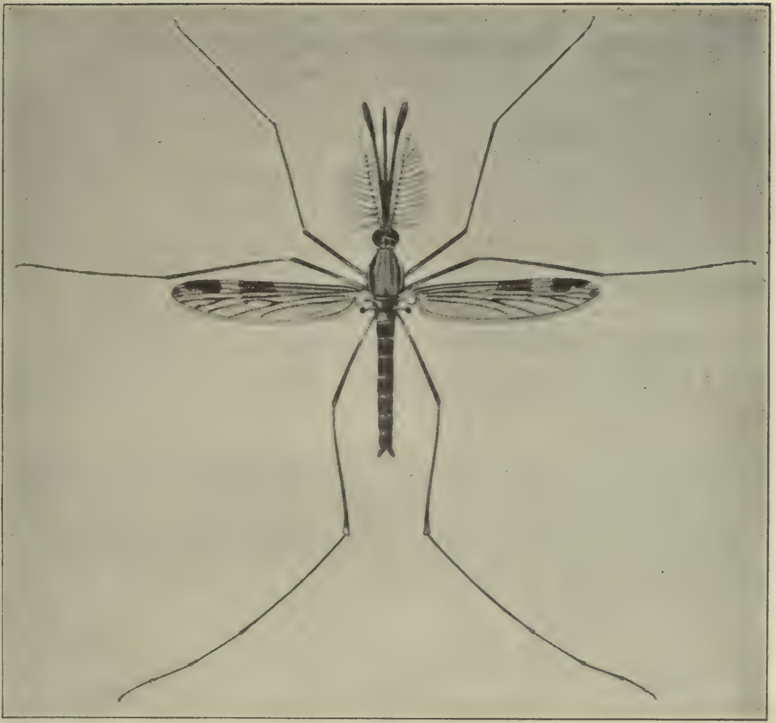

Fig. 10. Adult malaria mosquito (*A. punctipennis*). Male. Original.

of small streams. They feed upon algae, it is believed, and never appear in the water left in barrels and other utensils near dwellings. Swampy regions are generally most malarious because they furnish the best conditions for the multiplication of these mosquitoes. Yet they may be found breeding within the limits of such cities as Lexington, and are always ready to convey the malaria if it is at any time brought here from other localities.

While mosquitoes of all sorts can fly well and may thus travel about, they are always most numerous near their breeding places, and hence these should be the first to receive attention when we are endeavoring to get rid of the insects. Coal-oil on the water in buckets and barrels will destroy the yellow fever and brown mosquitoes. Draining swampy ground near dwellings will reduce the numbers of malaria mosquitoes. Oil may sometimes be used on ponds for the latter. Screens on doors and windows are necessary in both city and country if we would enjoy freedom from both mosquitoes and house-flies. The discovery that such diseases as typhoid fever and malaria are carried by these insects makes these effective barriers almost a necessity.

When mosquitoes have already gained access to rooms it is sometimes necessary to adopt other measures to get rid of them. Insect powder answers this purpose very well, being effective either when puffed freely into a room, or better, to avoid the

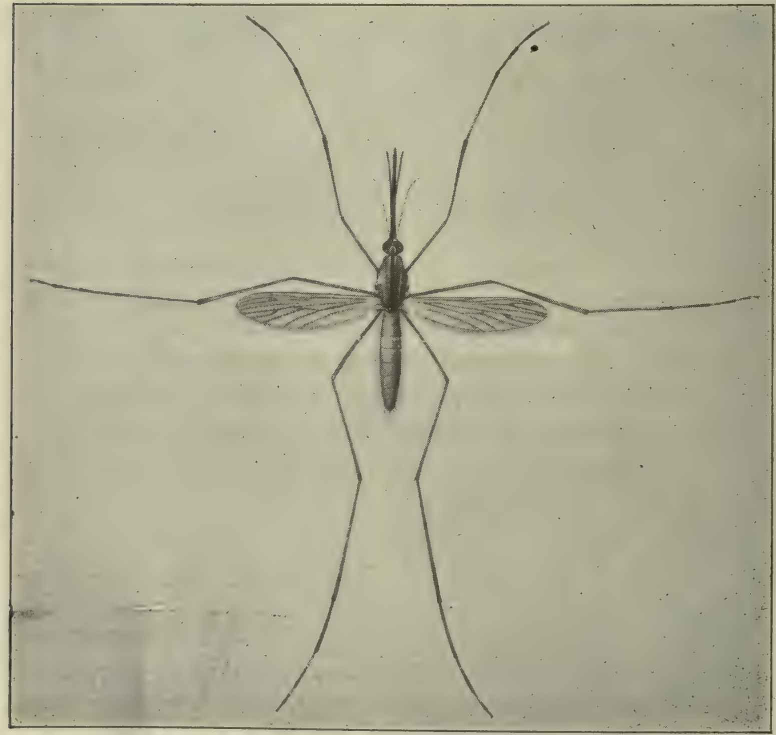

Fig. 11. Adult malaria mosquito (*A. maculipennis*). Female. Original

brown dust settling on furniture and bedding, may be burned over a lamp, being simply strewn on an old tin pan or other piece of metal and held over the flame. Oil of citronella rubbed on face and hands is a deterrent to mosquitoes, but not always the most satisfactory way of dealing with them in the household.

FLEAS.

The fleas frequenting dwellings are of several different species, according to the character of animal pets kept by a family. Dogs are notorious as breeding places for these insects and any lover of dogs is likely to suffer more or less from the presence of fleas about his place of abode. Yet it is sometimes a little amusing to hear people who keep such pets much of the time within doors, expressing wonder as to why the fleas "are so bad." If both dogs and cats are kept in stables and other outhouses, a chief source of fleas in dwellings will be removed, tho people who visit the quarters of their pets frequently are likely to bring fleas indoors on their clothing. It becomes necessary, if this is to be avoided, to keep the sleeping places of dogs particularly clean, the bedding being changed frequently, the animals themselves to be treated with sprays, dips, or powders, to keep the insects from becoming numerous in their coats.

The subject has become of more interest to us recently because of the discovery that fleas are carriers of certain human diseases. The readiest means of suppressing such diseases as bubonic plague has, accordingly, been found to be the destruction of rats and other rodents known to harbor fleas about dwellings. It is conceivable that other animals harboring fleas are sources of danger to us, also, and it behooves us to exercise all reasonable precautions against the pests, at any rate until we know positively the precise part taken by each one of the household pests and pets in the transmission of ailments to which we are subject.

Thus in dealing with fleas, as in the case of ants, it is of special importance to control the source, their natural breeding places, from which the pests come; and, further, to disinfect the animals we keep about us that are the chief means of bringing them into our dwellings. Practically all that needs to be done in the case of flea infestations is accomplished, when these precautions have been taken.

In the first place, it is desirable that the floors of stables and other outbuildings frequented by pets be made as far as practicable flea and rat proof. Wooden floors are to be avoided when possible because of the opportunity they afford for rats to burrow beneath, and for fleas to find crevices in which to breed and from which they cannot readily be driven out, or destroyed. A good concrete floor is almost a necessity as a means of providing cleanly quarters for animals. It holds both rats and fleas in check; it can be easily cleaned and even disinfected. Old litter, the refuse of bedding, forage, feeds, and the like, should be carefully swept up and burned or removed to the garden or farm to serve as a fertilizer. A little carbolized lime scattered about such places, in crevices of floors, etc., will help. Coal-oil, where it can be used, is excellent. Rat poisons and traps may be brought into service. All of these are well known and easily applied remedies, and if employed in advance of veritable irruptions of the pests will keep fleas suppressed.

While there are several hundred species of fleas infesting different animals, those commonly found about human habitations in this country belong to four species, which are:

The human flea (*Pulex irritans*), found also on the dog and other domestic animals, also at times on rats, and even on the skunk.

The dog flea (*Ctenocephalus canis*) which infests cats, dogs and many other animals. The commonest flea in dwellings in this part of the United States.

The cat flea (*Ctenocephalus felis*) infests cats and dogs. Frequently the common flea of dwellings, when cats are kept constantly indoors.

The rat flea (*Xenopsylla cheopis*). This is the plague-carrying species common in India and now introduced into

California and probably other states at seaports. In San Francisco where plague somewhat recently appeared it constituted, according to a census taken by Rucker, nearly twenty-two per cent. of the fleas found on rats, the human flea constituting 5.57 per cent. and the dog flea 0.52 per cent. The greater proportion (68.07%) of the fleas found on rats by this author belonged to a species (*Ceratophyllus fasciatus*), the common rat flea of the United States, sometimes attacking man, but different from the India species. This flea may not carry the plague, but this remains to be proved, and since a closely related species (*C. acutus*) infesting ground squirrels is known to carry the ailment, it is well to guard against any of the fleas, especially during times of special danger.

CLOTHES-MOTHS.

In June each year during, or a little after housecleaning time, one sometimes sees a small brown moth flit before him as he reads by lamplight. With a wavering flight it traverses the room if not knocked down and quickly destroyed by the irate housekeeper. A clothes-moth is one of the few livings things that gets no mercy at the hands of the women folk. A toad, or even a spider, has a fair chance for its life when they are about. And indeed it deserves no mercy. When our winter clothing is put away in wardrobes or closets and we leave home for a vacation these small mischief makers enter silently and begin their work of destruction. The eggs are placed about woolens and furs, and soon small worms or larvae begin to eat their way among them, making little holes thru the fabrics, releasing the hair of furs and cutting up generally, so that when these garments are taken out in the fall they may have been rendered unfit for wear.

Two species are common in Kentucky, both small brown moths when adult and belonging to a small group of families containing other mischief-working species, such as the grain moths and numerous leaf miners of cultivated plants and fruit trees. Our clothes-moths have probably been introduced from Europe, tho this is not certain, as the injuries have been known for centuries, and the insects were doubtless widely distributed over the globe at an early period of our history.

One of our moths (*Tineola biselliella*). is uniformly pale brown, the wings unmarked, narrow, pointed, and heavily fringed; about 0.18 to 0.20 inch to the tips of the folded wings. These moths appear in Kentucky in May and June, placing eggs during these months on any exposed woolen fabrics and among other animal products kept about us. The young of this insect makes no case until ready to become a pupa, when it spins a cocoon of silk attaching to it bits of gnawed particles so as to give it a rough exterior.

The second Kentucky clothes-moth (*Tinea pellionella*) is the more common of the two locally and at times, tho generally in households the other species is more often seen. This insect, when a larva, makes about itself a cylindrical case, open at each end, and these are often seen in numbers on walls and other surfaces about objects upon which the insect has been allowed to feed undisturbed for a long period. The moth is of the same general form as the other, but is plainly marked with several blackish dots. The pupae are formed within the cases in the spring of the year, the insect having wintered as a larva, and moths appear during the summer months.

If moths are already at work on garments it is sometimes best to fumigate with bisulfid of carbon. This can be done by placing the clothing in a chest and introducing a sponge saturated with the fluid and set in a bowl or saucer on top of the infested objects. Caution is necessary in using bisulfid of carbon because of the inflammable nature of its fumes. No fire should be brought about while the fumigation is going on.

Fumes of burning sulphur cannot be used safely because of their bleaching effect on the colors of fabrics.

Garments can be safely kept during the summer in tightly closed paper sacks or sealed strawboard boxes. Neat receptacles with hooks for suspending and of such size that garments like overcoats, business suits, and gowns, need not be folded, are on the market, and cost from 50 cents to $1.50 apiece. Under some circumstances saturating fabrics, like carpets, with ben zine or a first-rate gasolene can be made to destroy moths. When the fabrics themselves cannot be treated, it may in exceptional cases be desirable to fumigate with hydrocyanic acid gas, as recommended for roach infestations.

BEDBUGS.

Several species are known to attack man in different countries. The one occurring in America seems to be *Acanthia lectularia* and has followed man from the Old World. It is suspected of carrying several diseases such as dumdum fever or Kala azar of the East, and relapsing fever. Its habits and life-history are so well known as to render an account unnecessary. The Indian bedbug is *Acanthia hemipterus.* Other species of this country infest the bat and barn swallow, and when encountered about buildings have sometimes been mistaken for the true bedbug. The latter is long-lived and may persist for some time in deserted dwellings, but some cases supposed to be of this sort are the result of mistakes in identifying the insect.

The pest is especially likely to be troublesome in boarding houses, hotels, dormitories and barracks because of the miscellaneous character of those occupying them. Places of this sort require at least monthly inspections for such pests. The tidy housekeeper generally knows how to get rid of bedbugs by the use of coal-oil. They are most troublesome on wooden bedsteads. Iron bedsteads afford fewer hiding places and are more readily inspected. They are always to be preferred.

In the case of badly neglected quarters in which the bugs have become established in walls as well as beds it becomes necessary to fumigate with hydrocyanic acid gas, as directed in the section of this circular devoted to roaches.

ROACHES.

Three different species of these insects are found in dwellings in Kentucky and may be the source of a good deal of annoyance to the householder. Two of them are importations from foreign countries, the third is believed to have originated in America. Some additional roaches are found in our woods.

under stones or loose bark, and rarely come about houses. They are all active, running insects, belonging to the same insect order as the cricket and grasshopper, tho to a different family. The roach is an ancient type of insect which seems to have flourished during certain warm, moist periods of geological times, of which fact we have evidence in very well preserved fossil wings and other parts of their bodies. The group cannot be considered decadent yet, if we may judge from the statements of travelers in tropical countries. Roaches are often so numerous there as to become a veritable scourge, even attacking sleeping children and gnawing off their eyelashes, while foods of all sorts are literally devoured by the hosts of pests that come forth at night and run riot among provisions in storehouses and pantries. The accounts of their depredations on shipboard, particularly in olden times when man seemed to be completely helpless in dealing with them, are most shocking. Food is not merely devoured but that remaining is so covered with filth as to be unfit for human food.

The Croton-bug (*Phyllodromia germanica*).—The smallest and most commonly troublesome roach in Kentucky households is a small brown insect, both sexes provided with well developed wings which are longer than the body and lie flat on the back. On the shield-shaped piece just behind the head are two parallel black marks. The length to the tips of the folded wings is about 0.56 inch. This roach is supposed to have been brought here from Europe; at any rate it is not a native of this country. The fact that it is completely adapted to life in dwellings indicates that it is an old associate of man and probably originated where he did—in India or some other section of Southern Asia.

While all of the roaches are more or less noctural in habit, this one is often seen roaming about in the daytime, and sometimes helps itself before our eyes to food on tables of hotels and restaurants. The name Croton-bug appears to have been applied to it when the Croton aqueduct of New York was completed and the insect began to attract attention from its abundance about water pipes. It is now scattered thruout the country, but does not thrive in some households, while in others it becomes very numerous. It is uncertain why this is so, and an explanation of this feature of its prevalence might help us to get rid of it everywhere. For there must be some good reason for its absence from one place and its constant presence in another seemingly similar place of resort. Dr. L. O. Howard, some years ago, observed a migration in large numbers of this roach from a restaurant in Washington. The restaurant people were not at the time making war on roaches, so it is not unlikely that some insect or other predatory enemy drove them out. The life-history of this roach is briefly the following:

The eggs are produced within a brown rather firm capsule or case and may be carried about by the parent for some time before being dropped in some nook or crevice, behind baseboards or other woodwork, when the young hatch and at once begin an active life of foraging in the neighborhood, especially at night. As they increase in size the skin is molted from time to time until finally wings are acquired, when they are adult and ready to produce a new generation. It is believed that the entire development of an individual is accomplished in six months in the case of this species, which thus breeds more rapidly than the other domestic species. There is no quiescent pupa stage, such as is undergone by bees, butterflies and some other highly organized insects.

The Croton-bug thrives in some dwellings in a most exasperating way, not entirely because of its great capacity for increase, but because it keeps close to the artificially warmed parts of households and thus escapes the severity of winter. Brick or stone buildings kept well warmed in winter are, therefore, favorite haunts for the pest, and some of the very best and most carefully constructed buildings thus become infested; while more open frame buildings, not well warmed in winter, may be less often invaded.

TREATMENT FOR ROACHES.

The use of insecticides against roaches is a satisfactory means of suppressing them if it is persisted in, and especially if employed before the insects become very numerous. If only a few have by some chance been introduced, the ordinary insect powder (pyrethrum) of drug stores can be used to advantage about shelves and in crevices of pantries and storerooms. This is a non-poisonous powder, so can be strewn about very freely where food is exposed, tho it is desirable to cover the latter before the powder is employed. A powder gun can be used to advantage in scattering the powder. Applications should be made in the evening, and in the morning the dead and disabled insects can be swept up and burned. Insect powder does not retain its killing properties long after it is exposed to the air, hence it must be used frequently. Borax dusted freely and persistently about baseboards and on shelves is claimed to be as good as anything known.

Poisons are in common use that generally contain a small per cent. of phosphorous and are sold as "roach paste," with instructions for use. In drawers and storerooms where not likely to be secured by children or pets, they can often be made to answer even better than the insect powder. A package before me bears this inscription:

"*To Kill Cockroaches and Waterbugs.*—Apply the paste on pieces of paper and place in and about sinks, waterpipes, stationary wash-basins, etc. In the morning carefully burn these pieces of paper and dead roaches. Repeat every night until entirely rid of these pests."

Traps.—Ingeniously constructed traps have been devised for capturing roaches, and have in the hands of some people proved useful. A box with four pieces of glass inclined to a small opening at the center is said to be used successfully in France, a bit of cheese or other bait being placed in the bottom to attract the roaches. A glass ring surrounding an opening in the lid of a box similarly baited is said to serve the same purpose in England. Simply inclining sticks from a shelf to the top of a deep glass jar in the bottom of which is a bait, has been found to be effective for the purpose.

Fumigation.—When everything else fails people are sometimes driven to fumigating a whole house, or at least the rooms infested with roaches. This involves some expense and trouble, but may in exceptional cases be the only recourse. A case of this sort occurred recently at Lexington. A new brick house occupied by a family of careful people became so completely infested that in desperation they applied to us for assistance. The house measured about 40 by 40 feet and was two stories high. It was fumigated with the following:

Sodium cyanide, 20 lbs. av.
Commercial sulfuric acid, 3.75 gals.
Water, 7.50 gals.

This is at the rate of 1 ounce, av., of sodium cyanide, 1.5 ounces sulfuric acid, and 3 fluid ounces of water to each 100 cubic feet enclosed. It is more than is sometimes recommended, but it is well to do thoro work and take no chances of failure, since this involves a complete loss of time, and money expended. The extra precaution is necessary because of the difficulty of preventing leakage of the gas owing to badly fitted doors. windows, etc. In a small room, well caulked, the following dose, sometimes recommended, will probably be found sufficient. For each 130 cubic feet enclosed:

Sodium cyanide, 1 oz.
Sulfuric acid, 2 fluid oz.
Water, 2 fluid oz.

Small cupboards that can be tightly closed to prevent all escape of fumes may be fumigated with bisulfid of carbon instead of cyanide of sodium. This substance is sold as a fluid, commonly in pound bottles, and it is only necessary to pour the fluid in a dish or pan set on a chair or table and close the door. The fumes are poisonous, and also very inflammable, so that some care must be exercised to prevent their escape into rooms other than those being fumigated, and also to keep fire in any form away from them. The odor of bisulfid of carbon is disagreeable, but soon disappears when fumigated quarters are thoroly aired after the fumigation is completed. About 1 pound of bisulfid of carbon is used for each 500 cubic feet of space enclosed and the strong fumes should be kept confined for 48 hours.

Sodium fluorid dusted freely about baseboards and other frequented places can be made to destroy numbers of the insects.

The Oriental Roach (*Blatta orientalis*).—This is a brownish black roach somewhat larger than the Croton-bug, the female wingless, and the male with the wings shorter than the body and terminating bluntly, as if obliquely cut off, tho without angles. The male measures from about 0.80 to 0.88 inch in length, the folded wings reaching a short distance beyond the middle of the abdomen. Females are longer, measuring from 0.80 to 1 inch in length. The oval egg case is about 0.40 by 0.24 by 0.18 inch, each valve with about 16 minute marginal prominences and 8 submarginal swellings.

This insect sometimes becomes more numerous in dwellings than the Croton-bug and can be equally annoying to the tidy housekeeper. It is sometimes called the Black beetle, but it is not a true beetle, its relationship being with crickets and similar insects, instead, all belonging to the order Orthoptera.

Its manner of life so far as the household is concerned is the same as that of the Croton-bug. It feeds upon many different foods and attacks at times the bindings of books and various other substances useful to us and commonly kept about our dwellings. The same treatment is to be recommended as for the other insect, namely, poisoning, trapping, and, in extreme cases, fumigating.

The American Roach (*Periplaneta americana*).—Both the Croton-bug and the Oriental Roach have been introduced into America from some other country, in all probability from some tropical region, since they are sensitive to extreme cold and suffer from it. The American species, the third of those here dealt with, is a larger insect than either of the others and is fully winged in both sexes. It measures from 1.32 to 1.68 inches in length to the tips of the folded wings, is dark reddish brown in color, the shield-shaped plate (prothorax) just behind the head being bordered somewhat irregularly with yellow. This roach appears in our households less frequently than the introduced species, yet may make more trouble when it gets a foothold. It is a very active insect both on its feet and by the use of its wings, and being largely nocturnal in habit often does its mischief without being recognized as the culprit. The species is much like a smaller roach (*P. australasiae*) said to be common and troublesome in the more southern states. The latter has not been observed by me in Kentucky, but probably occurs here locally at times, since it has been observed in adjoining states. It measures about 1.35 inches in length to the tips of folded wings, being thus about the size of small *P americana*, and may be recognized by a bright yellow mark along the shoulder of each front wing. The yellow marginal band of the prothorax also is more sharply defined and conspicuous than in the closely related American insect

WHITE ANTS.

The common name of these insects leads us to expect them to be somewhat like ordinary ants in character and habits They are in fact only like ants in general appearance, and belong to an entirely different insect order. They are generally brought to our notice during their annual swarming flights, when great numbers of the gauzy-winged males and females emerge from retreats in timbers of buildings and scatter to mate and establish new colonies. At such times the householder is surprised by a horde of them coming from the base of a porch column, a sill lying close to the ground, or a wooden basement floor. They live ordinarily in burrows made in the interior of such wood and in the soil, and their mischief is thus accomplished before their presence is suspected. From infested woodwork they may invade other objects lying near, such as books and fabrics left in little used basement rooms, and have sometimes been the cause of severe loss in this way. Several years ago a package of printed reports of this Station was invaded in a basement room, the ants coming up to a set of shelves from a floor just beneath. Extensive galleries were cut in the leaves, the worst infested being completely ruined. In other cases observed by me posts of verandas were mined rendering necessary their removal

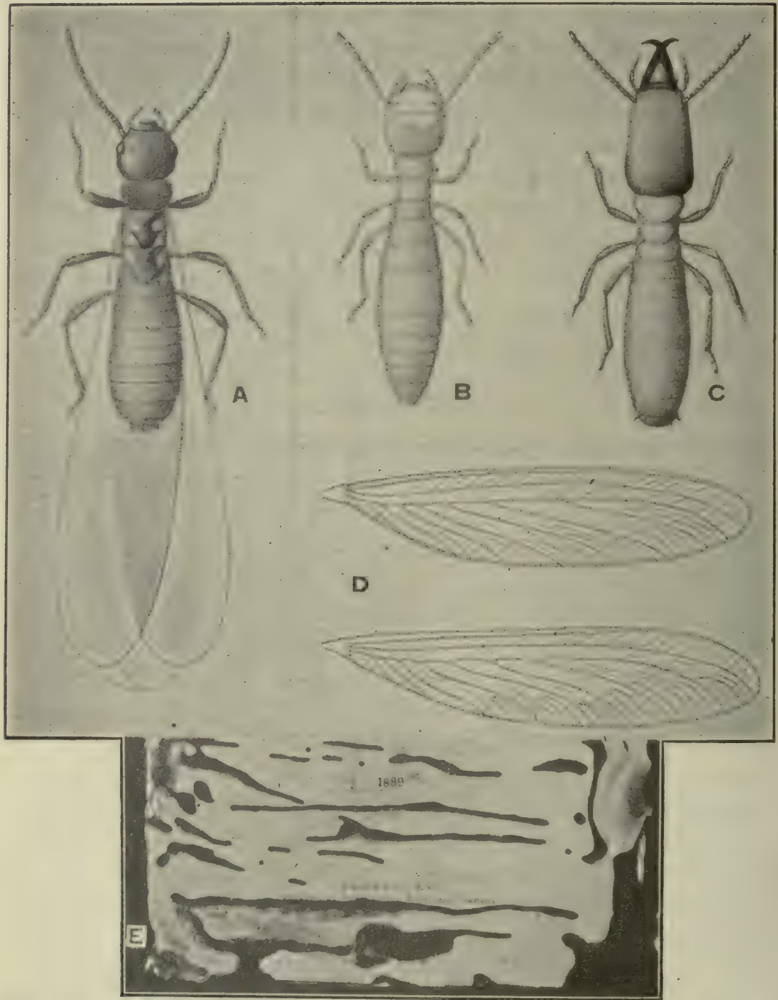

Fig. 12. The common white ant (*Termes flavipes*). A, winged form; B, worker; C. soldier; D, showing structure of wings; E, an injured pamphlet. Original.

With a knowledge of the habits of this insect extensive losses need not be sustained. A free use of insect powder about shelves on which books are kept, the injection of coal-oil or creosote in timbers, an occasional use of bisulfid of carbon, are all that is necessary to suppress them. Wooden floors close to the ground are always in danger from them, and should be replaced with concrete. The insect is naturally an inhabitant of fields and woods, where it lives under logs and stones.

White ants are remarkable because of their social life, colonies consisting of workers, males and females, which are sterile; of sterile soldiers, males and females, which defend the colony; a very large queen who has discarded her wings; a male who has discarded his wings; and, during the swarming season, many winged males and females. An almost equally remarkable feature of their economy is the presence in their digestive tubes of swarms of singular microscopic Protozoa, which belong to a peculiar family (Trichonymphidae) and are so far as known not found elsewhere on the globe.

SILVER FISH.

Most of us have seen at times a flattish silvery insect that runs rapidly over books and papers, or walls, when molested, and quickly conceals itself. It is so extremely fragile and soft-bodied that a mere touch will destroy it, but so quick that it generally escapes. Its scientific name is *Lepisma saccharina,* and it has the reputation of being fond of starches and sugars, tho the writer has never observed it about either stored sugar or starch. The assertion is often made, however, that it damages starched fabrics such as curtains and sometimes eats the starch paste used on wall paper so as to render the latter unsightly. Books are said to be damaged also, the insect being after the starch used by binders, it is thought. Some years ago at Lexington these insects were found in great numbers under the shingles on the sides of the upper story of a cottage from which retreat they invaded rooms, gnawed the wall paper and damaged the surfaces of photographic prints. Careful tests made at the time indicated that they were not feeding on starch.

but on gluey substances in the different papers and in the binding of books. The outer surfaces of photographic prints were scored exactly as were the surfaces of wall paper and the backs of books. Attempts made to poison them with starch paste and other similar substances, suggested by what I had seen in print about their food habits, failed, and it was only when glue containing poison was used that the insects were destroyed. It became evident from these observations that at least one of the silver fish species found in dwellings fed on animal food, and this was made more certain by finding individuals feeding on the bodies of their dead comrades. It must be admitted that there is a general impression, produced by many repetitions of old statements, that the insects feed upon starched fabrics, and it is certainly true that such fabrics have been at times damaged in households by some insect pest. As long as we do not know positively what insect does the mischief, the silver fish will probably be blamed.

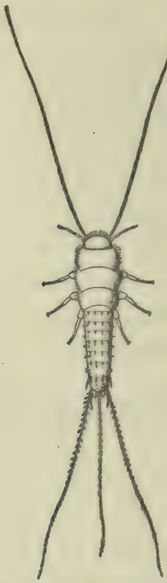

Fig. 13. **Silver fish** (*Lepisma saccharina*). **Adult. Original.**

Ordinarily these insects are not common enough to require treatment. A little insect powder dusted about tables and among papers may be sufficient. Wall papers, as far as my observations extend, are damaged in the regions about picture rails and window frames, the insects coming out from behind them at night to feed. Blowing insect powder into the crevices behind the frames is thus calculated to reach and destroy the silver fish in their lurking places. Glue moistened with water and dusted with arsenic will doubtless destroy many of them. A similar bait of starch paste and arsenic is sometimes used about shelves by librarians, but as already stated my own experience with starch baits indicates that they are valueless for some of the silver fish of our dwellings.

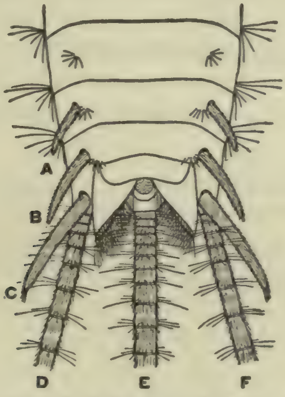

Fig. 14. Under side of tip of abdomen of silver fish showing, A, B, C, the pairs of imperfect limbs and, D, E, F, three terminal, jointed appendages. Original.

These insects measure nearly a half inch in length and as the name implies are silvery white, the peculiar gloss being due to microscopic overlapping scales with which the body is covered. There are no wings at any stage of their existence, hence there are none of those abrupt changes known as metamorphoses, so highly characteristic of most insects. A pair of slender feelers (antennae) arises from the head, while at the hind end of the body are attached three similar slender stylets very much like antennae in structure and appearance. The three pairs of legs are short but the thighs are especially strong, enabling the creature to run swiftly.

Note.—Such insecticides as borax, insect powder, corrosive sublimate and sulfur may be obtained of most local druggists; when not found in local stocks they may be secured from such firms as Eimer & Amend, of New York City; Arthur H. Thomas, Philadelphia; E. H. Sargent, Chicago; Grasselli Chemical Company, Cincinnati; Henry Heil Chemical Company, St. Louis. The following firms make a specialty of certain products and can supply them in quantity:

Edward R. Taylor, Penn Yann, New York—Bisulfid of carbon.

Roessler & Hasslacher Chemical Company, New York—Sodium cyanide.

West Disinfecting Company, 12 East 42d St., New York—Sodium fluorid.

Kentucky Tobacco Products Company, Louisville, Ky.—Tobacco extract.

Woodward & Lothrop, Washington, D. C.—Cases to exclude moths from garments.

FOREST

2

GIPSY-MOTH LARVÆ AS AGENTS IN THE DISSEMINATION OF THE WHITE-PINE BLISTER-RUST[1]

By G. Flippo Gravatt, *Assistant Pathologist*, and G. B. Posey, *Scientific Assistant, Investigations in Forest Pathology, Bureau of Plant Industry, United States Department of Agriculture*

INTRODUCTION

Very little has been done to correlate the widespread distribution of the white-pine blister-rust, caused by *Cronartium ribicola* Fischer, with factors governing the dissemination of the spores of the causal organism. The early occurrence of telia on leaves of currant and gooseberry plants (*Ribes* spp.) in localities distant from known infections on pines (*Pinus* spp.), together with the absence of definite knowledge of instances of overwintering on the former hosts, is suggestive of distant seasonal spread of the disease by æciospores from pines.

Larvæ of the gipsy moth (*Porthetria dispar* L.) feed on the Peridermium stage of *Cronartium ribicola* and carry thousands of æciospores on their bodies. As Collins[2] found that larvæ of the gipsy moth are blown as far as 20 miles, these insects are a potential agent in distant spread of the blister-rust. The gipsy moth is distributed over a large portion of the white-pine region of New England.

GIPSY-MOTH INFESTATION ON DISEASED PINE

In the fall of 1916 a stand of white pine covering an area of from 5 to 7 acres at Kittery Point, Maine, was found to be severely infected with *Cronartium ribicola*. This growth ranged from young seedlings to mature trees 80 feet tall and random ¼-acre plots in this area showed 65 to 100 per cent of the trees to be diseased. The number of infections on individual trees ranged from 1 to more than 300, and it was estimated that there were 75,000 to 100,000 separate infections in trees on this area.

In the infected plot gipsy-moth-egg clusters were found in varying abundance on limbs and stems of pines of all sizes, and were located from near the ground to the tops of the largest trees. In a number of cases egg clusters were present on the diseased bark, and in one instance four were located on a single canker.

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[1] The writers are indebted to Mr. A. F. Burgess, of the Office of Gipsy Moth and Brown-tail Moth Investigations, Bureau of Entomology, for helpful suggestions. Further work is being carried on in coöperation with the above office.

[2] Collins, C. W. dispersion of gipsy moth larvæ by the wind. U. S. Dept. Agr. Bul. 273, 23 p., 7 pl. 1915. Bibliography, p. 22–23.

——— methods used in determining wind dispersion of the gipsy moth and some other insects. *In* Jour. Econ. Ent., v. 10, no. 1, p. 170–176, 2 pl. 1917.

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On May 25, 1917, large numbers of gipsy-moth larvæ were found in and around ruptured blisters, and several days later some of the blisters where the presence of larvæ had been previously noted were empty, and spore production was apparently arrested. Subsequent observation on these blisters showed that no further spore production took place, while on the same cankers blisters which were artificially protected from larvæ continued to produce spores in abundance until June 25. To determine the rate of blister destruction on June 9 a number of larvæ were placed on a twig infection which had 38 sporulating pustules. Many of the larvæ crawled away or dropped off, but a sufficient number remained to destroy the fruiting layer in practically every blister by noon of the following day, with the result that no subsequent spore production took place.

Cessation of spore production in injured blisters was caused by the destruction of fruiting hyphæ. Usually the spores and hyphæ were eaten away first and then the larvæ very often ate through the base of the fruiting layer to a depth of several millimeters. Apparently, after blisters no longer furnished suitable food for the larvæ, they began feeding on the areas of the yellowish, discolored, infected bark outside the fruiting region and in some cases a large per cent of the outer bark of next year's sporulating zone was destroyed. Careful observations on many larva-infested cankers showed that spore production was prematurely arrested in 25 to 100 per cent of the pustules, the percentage usually averaging highest on small twigs.

SPORES ON LARVÆ

Larvæ working in blisters collected so many æciospores on their hairy bodies that they appeared nearly the color of spores in mass. On different dates larvæ were taken from blisters and placed in separate capsules, precautions being taken against including spores not on the bodies. These were taken into the temporary laboratory and spore counts made of the bodies and the alimentary tracts. Spores for counting were removed from larvæ by washing the bodies in series of water, and alcohol mounts on slides followed by final examinations to assure thoroughness in the method used. This procedure proved quite effective, and, where carried through 5 to 10 washings, practically all spores were removed from the outside of the bodies. Counts were made on the spores adhering to the inside of the capsule and added to the total found in the washings. After bodies of the larvæ had been thoroughly washed, they were dissected and counts made of spores in the alimentary tracts. On May 26, June 4, and June 11 fifteen small larvæ were collected. Spore counts on the bodies of these 15 gave a minimum of 1,120, a maximum of 28,320, and an average of 18,100. Counts of spores in the alimentary tract gave a minimum of 1,740, a maximum of 48,570, and an average of 26,022

To determine the approximate amount of spore material passed through the alimentary tract, 20 larvæ were placed on fresh cankers in a feeding tray. After they were settled and had fed normally for several hours, a sheet of paper was placed under the cankers for the collection of pellets. A total of 423 pellets were dropped within a period of 13 hours. Counts of the spores in these pellets gave from 3,960 to 12,450, with an average of 8,160, which is at the rate of 318,616 spores excreted per day per larva.

Germination tests made of the spores on the bodies of larvæ collected on cankers gave positive results, and approximately the same percentage of germination was observed as on spores taken directly from these cankers. Germination tests of spores in pellets have given very poor results; in only one case did several spores germinate. In many cases spores taken directly from these cankers also failed to germinate in laboratory tests.

WIND DISPERSION OF LARVÆ AS A FACTOR IN BLISTER-RUST SPREAD

At Kittery Point, Me., æciospores were produced from April 29 to July 1, with maximum spore production from May 10 to 25. Collins[1] gives the hatching period for gipsy moth larvæ in this section for 1912, 1913, and 1914 as May 1 to 23, April 29 to May 14, and May 11 to 28, respectively. The season of 1917 was approximately one week later than usual. The period of wind dispersion of larvæ is given as ranging from 18 to 30 days, starting one to two weeks after the first caterpillars hatched. Observations by the writers showed varying numbers of larvæ feeding on blisters from May 25 to June 25.

Collins[2] working with wind dispersion of larvæ of the gipsy moth over a series of several years showed that they were carried in wind currents to distances as great as 20 miles. The same author states that approximately 50 per cent of the larvæ caught at distances of 6 miles or less had fed previously.

The writers, using fly-paper traps, placed 10 to 30 feet from the nearest pine infection, and so arranged as to exclude larvæ that may have reached the trap by crawling, caught 75 small larvæ. Four of these caterpillars had, respectively, 35, 105, 185, and 2,180 æciospores on their bodies, which establishes the fact of local wind dispersion of æciospore-bearing gipsy-moth larvæ. That spores carried on bodies of larvæ may remain viable for a considerable length of time is borne out in viability tests under laboratory conditions, wherein æciospores germinated after remaining in vials for a period of two months.

Examination of wild and cultivated species of Ribes at various points throughout Kittery Township showed an abundance of gipsy-moth larvæ feeding on the foliage, and in many cases they were observed crawling on the under surfaces of leaves. Quite a number of the larva-infested plants showed areas producing uredospores, and in four instances the only leaves showing blister-rust infections were those which had been injured by insects.

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[1] COLLINS, C. W. 1915. Op. cit.

[2] COLLINS, C. W. 1917. Op. cit.

Sixty larvæ collected on species of Ribes were examined for æciospores. Of these one larva collected on June 14 on the under surface of a wild gooseberry plant showed 280 æciospores and 520 uredospores on its body. The gooseberry plant was heavily infected with blister-rust, being located only 20 feet from pine infections. Germination tests of the spores from this larva gave two germinating æciospores and many germinating uredospores, thus bearing out the fact that gipsy-moth larvæ do carry viable spores to *Ribes* spp. and also showing the part which insects may play in local distribution of the disease by uredospores.

PRACTICAL IMPORTANCE

The facts given in regard to the gipsy-moth larvæ show that these insects are certainly a factor in the spread of the blister-rust locally from pines to *Ribes* spp. Their habit of feeding and crawling over the lower leaf surface, where the stomata are located, gives the spores borne on their bodies a good opportunity for causing infection. The probability of the spread of blister-rust from pines to distant *Ribes* spp. is undoubted, since Collins' work shows that the gipsy-moth larvæ are blown by winds of varying intensity for distances of 20 miles. Though wind is considered to be the most important factor in æciospore dissemination, gipsy-moth larvæ undoubtedly play an important part. Other insects have been collected from infected pines with thousands of æciospores on their bodies, but these insects were not present in sufficient numbers to make them of importance in comparison with the number of gipsy-moth larvæ present.

SUMMARY

(1) The period of hatching and of wind dissemination of gipsy-moth larvæ came within the period of spore production of the blister-rust on pines.

(2) Larvæ fed abundantly on spores and injured the fruiting layer of the pustules so that further spore production was arrested.

(3) Larvæ from blister-rust cankers had thousands of viable spores on their bodies. A small percentage of the larvæ collected from fly paper and from species of Ribes near infected pines showed æciospores on their bodies.

(4) Gipsy-moth larvæ were found feeding on leaves of *Ribes* spp., and in some cases the only infected leaves on plants of this genus were those showing insect injury.

(5) The Bureau of Entomology has shown that these larvæ are blown by the wind up to a distance of 20 miles. Within this distance the larvæ are potential agents in the spread of the white-pine blister-rust (within the area infested by the gipsy moth).

THE CODLING MOTH

(Carpocapsa pomonella L.)

By HAROLD R. HAGAN

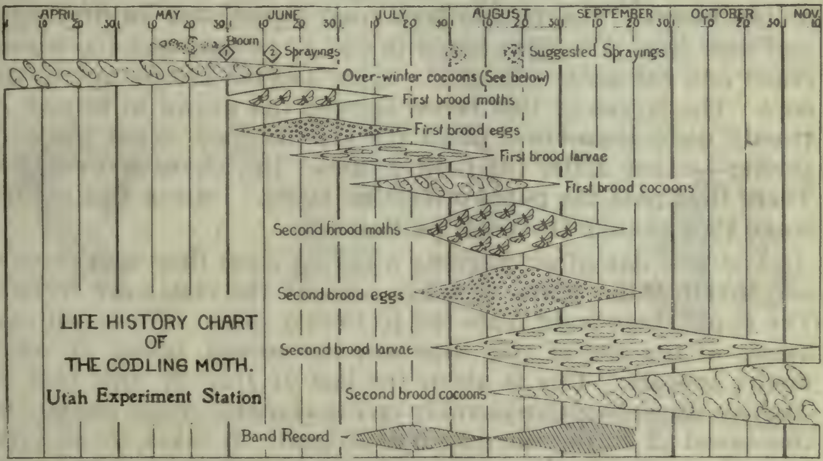


Chart showing life history of the codling moth with suggested times of banding and spraying.

CIRCULAR NO. 30

Utah Agricultural College
EXPERIMENT STATION

Logan, Utah March, 1918

THE CODLING MOTH

(Carpocapsa pomonella L.)

By HAROLD R. HAGAN

The Utah Experiment Station bulletins originally published, outlining satisfactory methods for reducing injury by the codling moth, are no longer available for distribution. This circular contains in briefer form the essential information for controlling the pest.

LIFE HISTORY

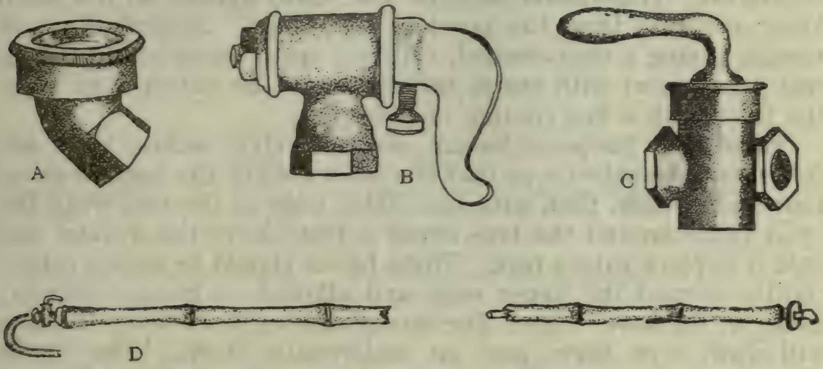
The moths appear from one to three weeks after blossoming time of the apples and lay their eggs usually on the upper side of the leaves. The female lays from twenty-five to fifty eggs and then dies. The eggs hatch in about ten days and the worms crawl into the *calyx end of the apple* and eat their way to the core. The larvae of this brood become full grown in fifteen or twenty days, then crawl down the tree to find some place of shelter—either under the bark or under the leaves and rubbish. There they pass the pupal or resting stage. During this resting stage they change from worms to moths.

The first day after reaching a hiding place they spin cocoons and within these silken sack-like cocoons the pupae are formed. The pupal stage lasts from ten to twenty days. The pupal case bursts at the end of this time and the second brood of adult moths appears. This is about the last of July or the first of August, depending considerably on the climate. Eggs are laid by this brood all during the month of August. It takes, on an average, seven days for the eggs to hatch at this time of the year. The worms hatching from these eggs bore into the side of the fruit and eat the pulp, usually penetrating to the core. They become full grown in twenty days, then seek shelter under rough bark, bands, or rubbish to pass the winter.

As soon as a shelter is found they spin cocoons and remain as larvae over winter in these retreats. Just before blooming time next spring these larvae change to pupae and in about three weeks the adult moths come forth from the pupae. This in brief is the life cycle of the codling moth. (See chart on the cover.)

CONTROL MEASURES

Spraying: In controlling the codling moth the most important feature of the work is to apply an efficient spray at the right time. A first-class pump maintaining a pressure of about 150 pounds is necessary. A hand pump may suffice for a very small orchard, but for a large orchard a power outfit is imperative. Spraying should be done from the top of a scaffold or ladder so that the man doing the spraying is a little above the center of the tree. Generally the blossoms all point outward; therefore, the spray should be driven down from the top, in from the side, and up from the bottom of the tree. The hose should be long enough to do the work readily and strong enough to stand the pressure. It is best to use a seven-ply hose. The spray rod should be a ten-foot bamboo pole. It should be fitted with a cut-off valve at the base and with a drip ring and 45 degree angle at the nozzle end. (See Figure). The cut-off should be used to save spray material while passing from tree to tree. The nozzle for the early spraying should be one that gives a driving, fan-like spray, which will not break into a mist until it has left the nozzle for at least five feet. The spray used is arsenate of lead —about three pounds of paste or one and one-half pounds of powder to fifty gallons of water. Care must be taken to keep the mixture constantly agitated so that the arsenate of lead will not settle to the bottom. The spray should be applied three to five days after the petals begin to fall, *with the sole object of filling each calyx cup with the poison.* It makes no difference if it touches the rest of the tree. "It is not a question of how much you spray, but of how well you spray."



A, "Mistry" nozzle fitted with 45 degree angle; B, "Bordeaux" nozzle, the correct type of nozzle for the driving spray; C, Cut-off valve used to economize on spray; D, Section of spray rod showing attachment of hose, cut-off valve, brass or copper rod in the pole, drip ring and 45 degree angle ready for attachment of nozzle.

A second spraying, similar to the first, should be applied ten days later. This will complete filling the calyx cups that are not open as early as the first spraying. These sprayings usually cannot be done at one time as a number of the cups are closed before others are open. If the calyx cup is closed it is too late to apply any spray for the first brood. In applying the spray, the outfit stops just before the men spraying the orchard reach a point opposite the center of the first trees of the first two rows.

Two men may apply the spray. They should spray the nearest third of the tree opposite them in the row, then they drive the outfit forward a few feet that they may spray the remainder of the first two trees and the first third of the second two trees. This method is continued until the end of the row is reached when the outfit is turned down the second row. Spray a third of the tree each time even if the sprayings overlap. It is poor economy to miss poisoning any calyx cups.

Inspection. Somewhat later an examination of the orchard will show whether ten per cent of the apples are wormy. If the spraying is done right there should not be ten per cent of wormy apples in the orchard. If there are more than this number, a third spraying should be applied about fifty days after the first brood of moths are thickest in the orchard, about the first of August. This should be a fine mist spray applied with a much lower pressure than the previous sprayings. Several types of nozzles giving a cone-shaped, whirling spray have been used by this department with entire satisfaction. The object is to cover the fruit with a fine coating of poison.

Banding: Strips of burlap about twelve inches wide are folded once lengthwise so that the inner fold of the band is about four inches wide, then with the folded edge at the top, wrap the band twice around the tree about a foot above the ground and hold it in place with a tack. These bands should be drawn rather tightly around the upper edge and allowed to hang somewhat looser at the lower edge. The larvae coming down from the tree will crawl over them and up underneath them. The bands should be put on about the time the first few worms begin coming down from the tree (July first). This will be about twenty-five or thirty days after the eggs are laid for the first brood. The bands should be taken off and examined every seven or eight days and the bands should be replaced after each examination. All the first brood of worms come down by the last of August. All the worms under the bands should be killed. After August the bands may be left on until the apples are picked; then they should be taken off and all the late second brood worms found under them should be killed. The bands can now be put away for the winter.

Besides these methods of control, the orchardist should examine the rough bark of each tree and into all cracks and crevices to kill the larvae that may be hidden there. Old bark should be scraped from the tree as it will, if left on, afford protection for the worms. Birds, ants, beetles, and some parasitic bees prey upon the eggs and worms and assist in the natural means of control.

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L. O. HOWARD, Chief

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SOLID-STREAM SPRAYING AGAINST THE GIPSY MOTH AND THE BROWN-TAIL MOTH IN NEW ENGLAND.

By L. H. WORTHLEY, *Agent in Charge of Scouting and Extermination Work, Gipsy and Brown-Tail Moth Investigations.*

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INTRODUCTION.

In nearly all parts of the United States damage is produced each year by leaf-eating insects, and the application of arsenicals, in the form of poison sprays, has been demonstrated to be the most efficient method of suppression or control. In the work of suppressing and preventing the spread of the gipsy moth and the brown-tail moth, spraying with arsenate of lead on an extensive scale has proved a very important factor. The magnitude of the insect problem which the ravages of the gipsy moth has developed in the New England States made it necessary to devise extensive improvements in insecticides and spraying machinery.

HISTORY.

When the work against the gipsy moth was first undertaken by the Commonwealth of Massachusetts, the problem was one of extermination rather than repression, and spraying with arsenical poisons at that time was not regarded as an important factor. The State Board of Agriculture of Massachusetts later conducted experiments with insecticides which resulted in 1894 in the development of arsenate of lead as the most economical and effective poison for control work against leaf-eating insects. After these demonstrations, spraying became more general, owing to resulting effectiveness as well as to a considerable reduction in expense, and this naturally led to the modification and improvement of machinery and apparatus for applying mist sprays.

In 1895 the late J. A. Pettigrew, while superintendent of Prospect Park, Brooklyn, N. Y., began solid-stream spraying, and in the Yearbook of the United States Department of Agriculture for 1896 there appears an article by Dr. L. O. Howard on the subject. The sprayer assembled by Mr. Pettigrew had steam as its motive power, the pump and engine being connected to a watering cart. (Pl. II.)

Owing to the discontinuance of appropriations by the Legislature of Massachusetts, the gipsy-moth work was stopped in 1900, and no State work was carried on in combating this pest until May, 1905, when a further appropriation was made.

In 1905 the late Gen. S. C. Lawrence, of Medford, who was intensely interested in the work of combating the gipsy moth on his large estate and others surrounding it, saw the necessity of larger machines for spraying and purchased a high-power machine which was operated by an air-cooled gasoline engine and had a triplex cast-iron pump. This machine did very good work, but its use indicated that further improvements were desirable.

Through the efforts of the writer, while in the employ of the State of Massachusetts, some important mechanical devices in solid-stream spraying were constructed, and during the last few years, while carrying on the scouting and extermination work for the Bureau of Entomology, United States Department of Agriculture, further improvements have been made. Many of these improvements are now being extensively used in New England, but in order that others contemplating the use of such apparatus may know the most economical and practical methods the following suggestions, illustrations, and tables are submitted.

After a careful inspection of the territory surrounding the known infested area in Massachusetts, it was found that it had increased from 359 square miles in 1900 to 2,500 square miles in 1905. It was apparent that a considerable amount of spraying must be done, but the apparatus available for so large an operation was insufficient and indequate, there being hardly any spraying machinery on the market except that principally used for orchard spraying. After the first season's work efforts were made to improve spraying machinery, so that the work could be brought to a higher degree of efficiency. Our efforts led to the construction of a high-power solid-stream machine, which was an improvement over those used in the previous season. These machines were assembled from stock parts purchased in the open market and consisted of stationary engine, with battery ignition and single cylinder or duplex pump.

While the results accomplished were an improvement, they were not satisfactory as the pump did not furnish a steady pressure and the engine caused too much vibration. In 1907 a two-cylinder marine engine and triplex cast-iron pump were used. This machine was an improvement over the first, but the pump would not stand high pressure and its use resulted in a large amount of valve trouble. Later a four-cylinder marine engine was used with high-tension magneto and a triplex pump made of phosphor-bronze having metal valves. This proved satisfactory, and practically the same outfit is in use to-day.

DESCRIPTION OF APPARATUS.

The high-power solid-stream sprayers being used by the Bureau of Entomology are assembled as follows (Pl. III):

Caravan running-gear, U-shaped tank, phosphor-bronze pump, 14-horsepower marine engine. Running gear built of best oak stock with high-grade iron. Wide tires on wheels, cut-under front wheels, with springs all around, fitted for a two-horse hitch. Tank made from select pine stock, capacity of at least 400 gallons, with a solid roof capable of carrying supplies on the top. An arch made of heavy steel straps is bolted on the inside to protect the agitator. This arrangement provides space in the tank for storing the hose while the sprayer is being moved from place to place and eliminates the need of a supply wagon, reducing the cost of operation about $5 a day. The roof extends over the engine, and side curtains are used to protect it from weather. Pump, triplex type, with cylinders, valves, valve chambers, and plungers made of a high-grade phosphor-bronze with a tensile strength of 35,000 pounds per square inch. This makes a much lighter and more compact pump than would be safe if cast iron was used, as the latter rarely has a tensile strength of more than 15,000 pounds per square inch. The cylinders and displacement chambers are cylindrical in design, so as to offer no flat surfaces to pressures; thus greater strength can be secured with the same amount of metal. The valves and waterways are extra large to permit high speed while filling. The valve chambers are so designed that any one valve may be removed without disturbing another. The uprights are made of high grade iron with babbitted bearings. The crank is a drop-forging which usually has an elastic limit of over 74,000 pounds per square inch and is not subject to crystallization. Cast-iron cranks should be avoided, as they usually have an elastic limit not exceeding 40,000 pounds. The pump is attached to the engine by a durable clutch, with gear and pinion. Connected with the pump are two automatic safety release valves, one set at 300 pounds and the other at 350 pounds. By having two release valves a variation of pressure can be obtained from 275 pounds to 375 pounds without making any change in the release valve and not running the engine at an excessive rate of speed. These valves are properly set and should not be adjusted in the field.

THE ENGINE.

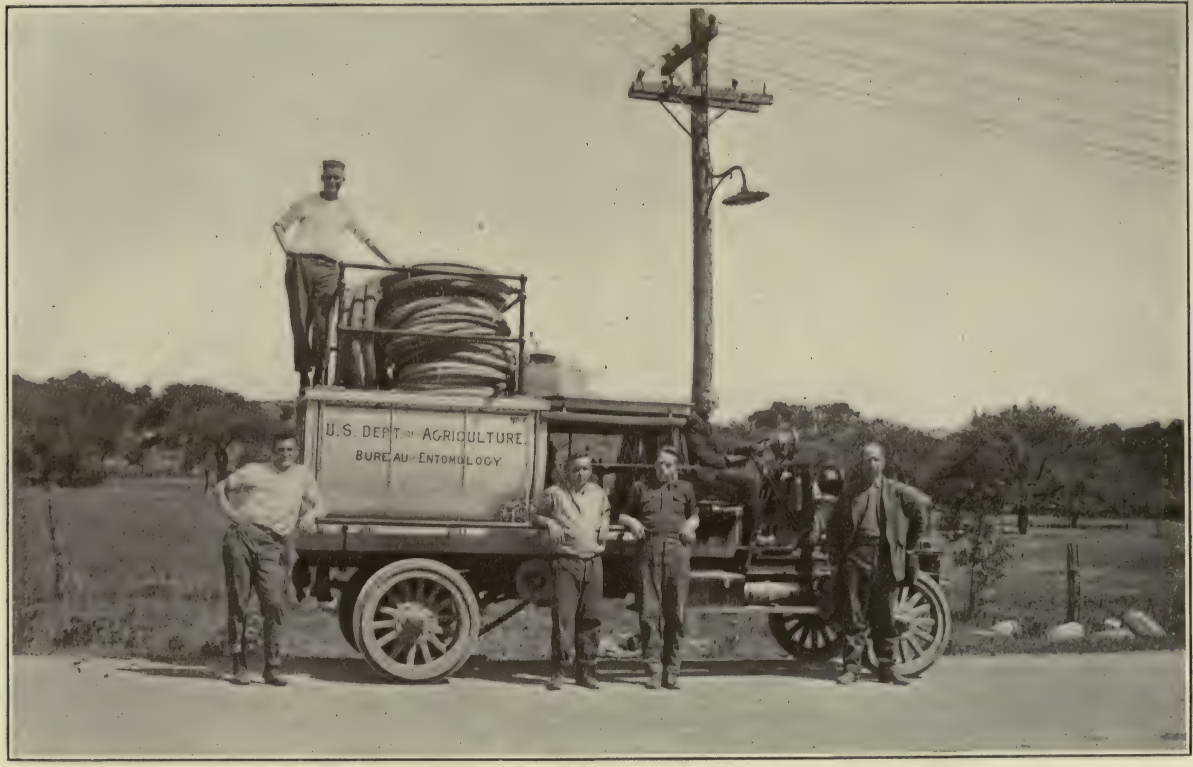
The engine is a 4-cycle, water-cooled type, having four cylinders, with a maximum of 14 horsepower, and is equipped with a high-tension magneto, and so oiled as to require little attention from the engineer. The cooling system consists of a coil of pipe submerged in the spray tank and fed by a supply tank located near the engine. The gasoline tank has a capacity of 10 gallons. The agitator consists of three long paddle blades extending the entire length of the tank and has proven more satisfactory than single propeller blades.

The safety or release valve is so arranged on the delivery line that the solution is automatically released into the spray tank whenever the nozzles are shut off. The piping, wherever subjected to high pressures, is extra heavy, with double-strength fittings, and is so arranged on the pressure side that the solution may be delivered into the hose for spraying or diverted into the tank when filling. The suction line is arranged so that the solution may be drawn directly from the tank or water from the suction hose when the tank is being filled.

While this arrangement is not essential in spraying work, it enables this apparatus to be used for other purposes, such as fighting fires, etc.

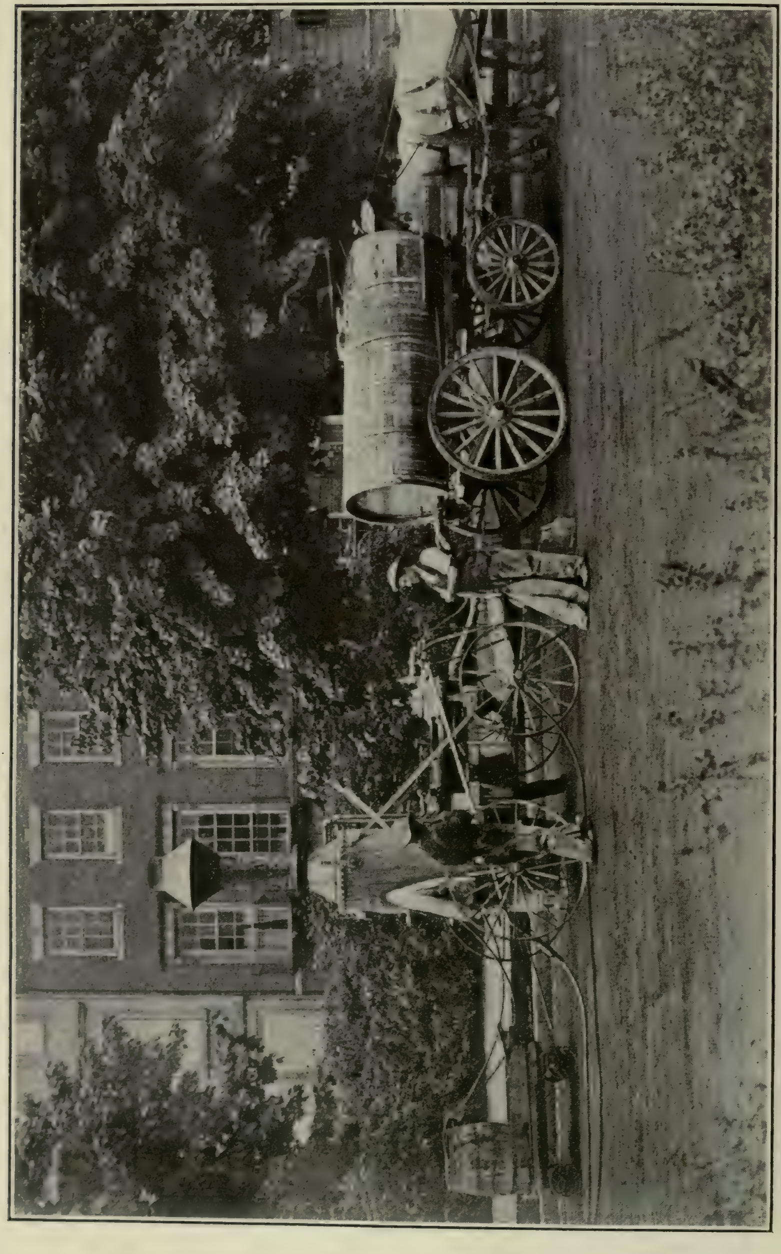
THE HOSE.

Hose used in high-power solid-stream spraying should be constructed to stand a working pressure of 600 pounds, with couplings especially adapted for high-power work. Hose used in this work not only has to stand high pressures, but is also subject to severe strain in pulling and hauling that is necessary especially in woodland spraying. Unless a very high grade 10-ply hose is used, with heavy inner tube and outer walls, it is advisable to have 7 or 8 ply hose covered with a cotton jacket treated to prevent mildew and increase wearing quality. It is also advisable to use high-grade hose, whether covered or not, as the life of it will be so extended as to reduce the yearly cost to a considerable extent. Couplings should be constructed so as to make it impossible for them to blow off under pressure and to offer as little resistance as possible when the hose is being pulled. In woodland spraying parts protruding from cou-



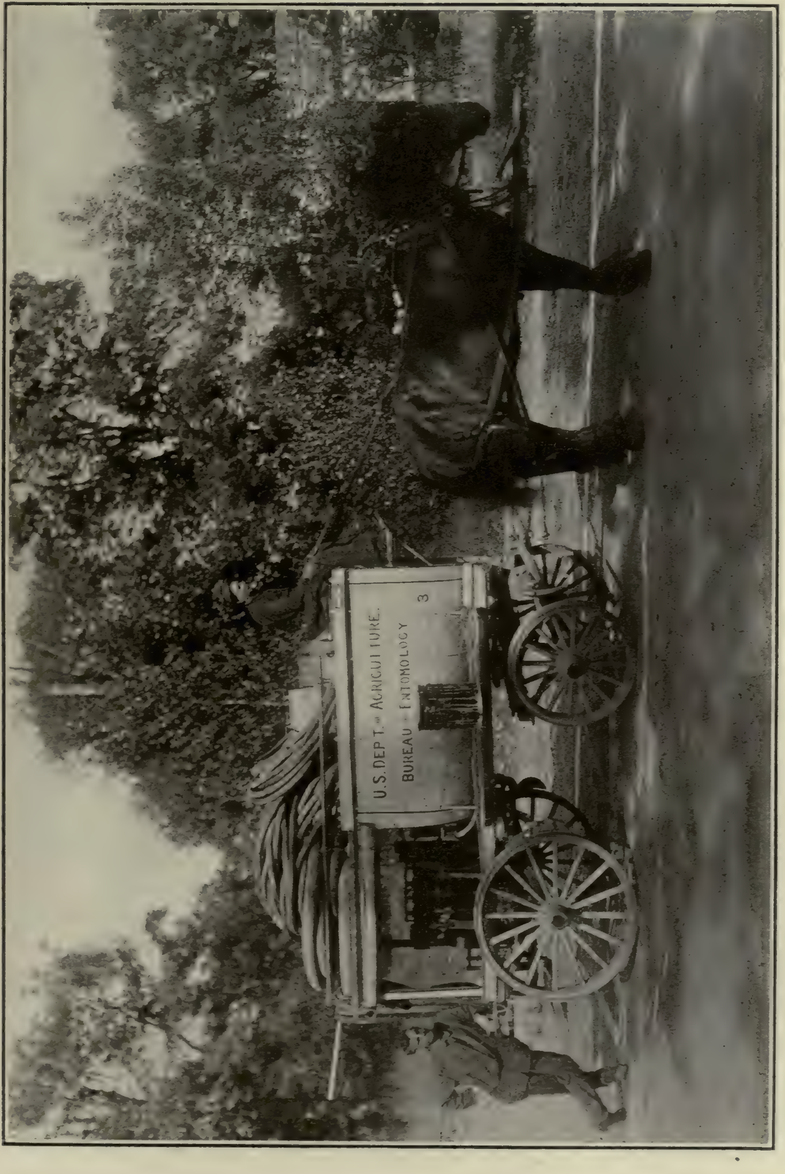
SPRAYING AGAINST THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

Motor-truck sprayer of the Bureau of Entomology with crew and equipment. (Original.)



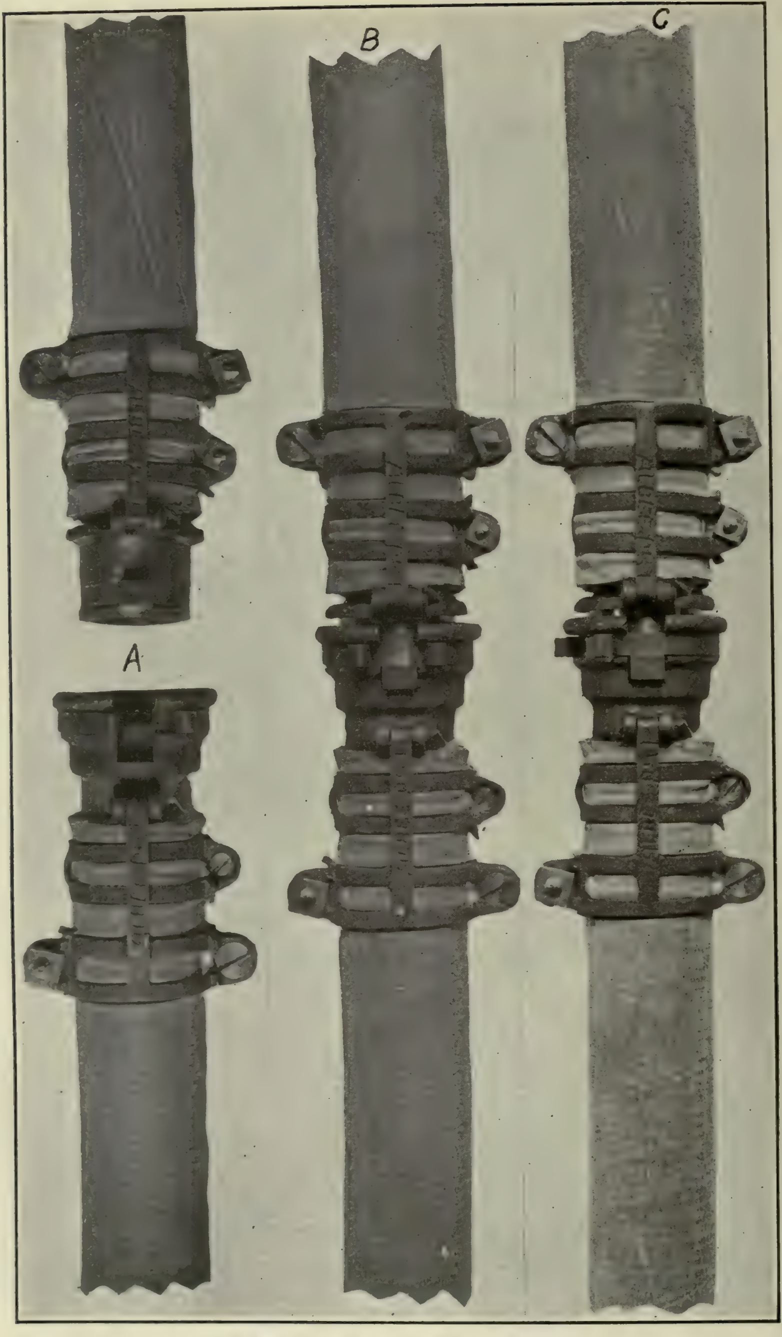
AN OLD TYPE SOLID-STREAM SPRAYER.

Sprayer built by Mr. J. A. Pettigrew and used in the Boston parks in 1907. (Original.)



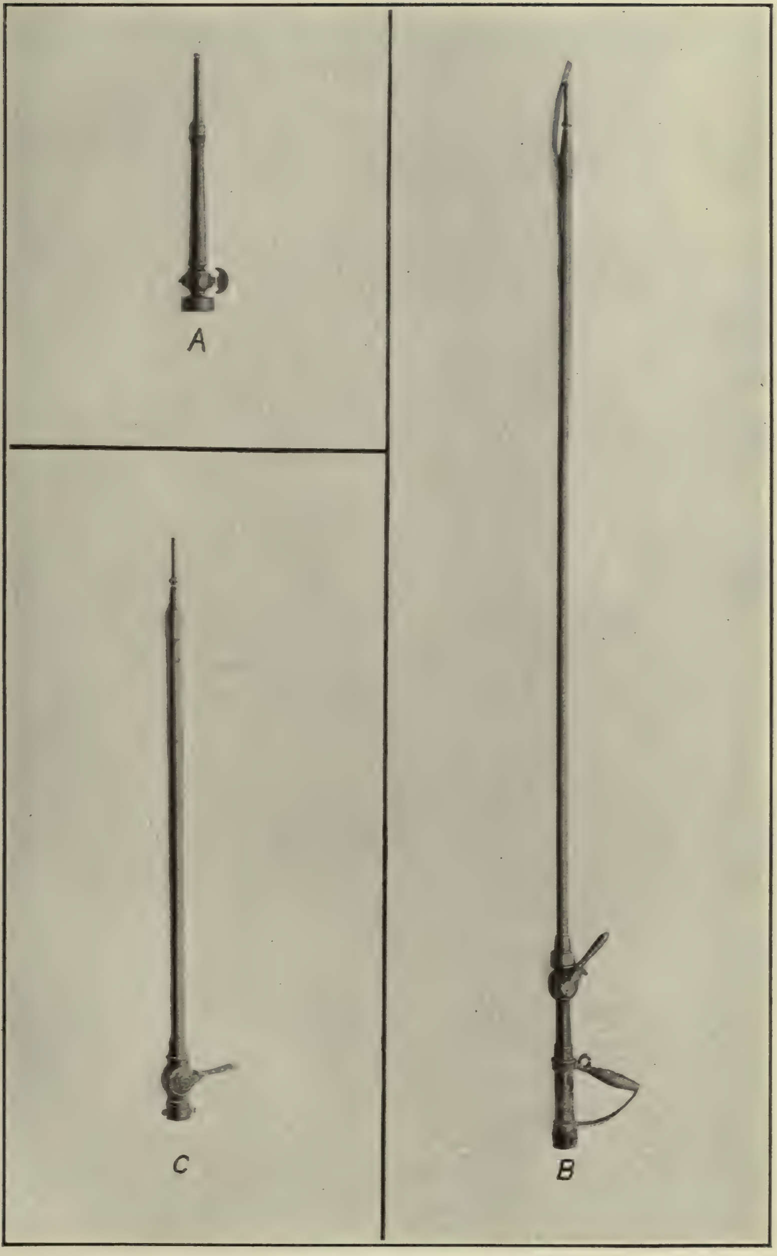
THE SPRAYING OUTFIT IN USE TO-DAY.

Present type of horse-drawn high-power solid-stream sprayer with equipment. (Original.)



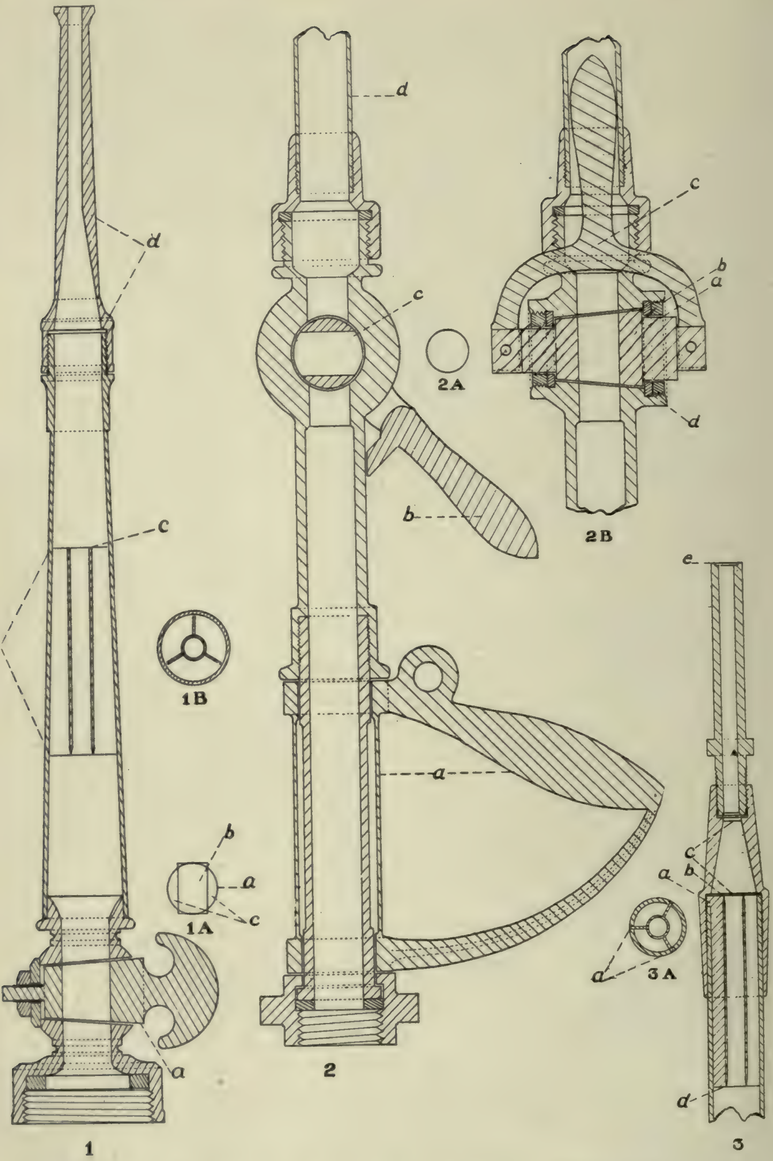
A NEW FEATURE IN HOSE COUPLINGS.

High-power hose equipped with quick-hitch couplings. A, Uncoupled; B, coupled but not fastened; C, coupled and fastened. (Original.)



COMPARISON OF OLD AND NEW TYPE NOZZLES.

Nozzles for solid-stream sprayer. A, Old type nozzle; B, latest type, known as the Worthley nozzle, with spreader; C, smaller size, same type as B. (Original.)



COMPARISON OF DETAILS OF THE OLD AND THE IMPROVED TYPES OF NOZZLES.

FIG. 1.—Old type nozzle. *a*, Shut-off open; *b*, Hopkins; *c*, square top of Hopkins; *d*, taper at base of tip. FIG. 1A.—Square waterway in shut-off; *a*, opening of pipe above and below shut-off; *b*, rectangular opening in shut-off; *c*, protruding shoulder in shut-off when open. FIG. 1B.—Cross section of tube and Hopkins, showing Hopkins loose in the chamber of the nozzle.

FIG. 2.—Base of Worthley nozzle. *a*, Swivel handle; *b*, shut-off handle; *c*, shut-off closed; *d*, base of tube of nozzle. FIG. 2A.—Clear waterway in shut-off when open. FIG. 2B.—Details of the shut-off; *a*, shut-off open; *b*, nut; *c*, shut-off handle; *d*, washer.

FIG. 3.—Tip of Worthley nozzle. *a*, Method of holding Hopkins in position in top of tube; *b*, top of Hopkins leveled to sharp edge; *c*, condensing head in end of tube; *d*, beveled base of Hopkins; *e*, protecting shoulder. FIG. 3A.—Cross section of tube and Hopkins. *a*, Hopkins firmly held in place at top of tube. (Original.)

plings are a great hindrance to the work, as they become entangled in twigs, rocks, and other obstructions. Recently there has been placed on the market a quick-hitch coupling that is easily connected without the use of wrenches and is being used by this Bureau in its spraying work. It promises a great saving in time when long lines of hose are being used. (Pl. IV.)

NOZZLES.

From observations made by the writer on solid-stream spraying operations in 1907, 1908, and 1909 it was evident that the nozzles being used were not giving satisfaction and that some improvement should be made. The nozzle then in use had a long, tapering tube with the shut-off near the tip or at the base and was constructed so as to offer considerable resistance to pressure. (Pl. V, *a.*) The "hopkins" (a finlike arrangement used in open-bored nozzles to stop the circular movement) was placed near the hose end and the tips were tapered nearly to the end, which caused the stream to spread, by reflex action, immediately after leaving the tip. Water passing through lines of hose takes a spiral motion, owing to the spiral winding in the manufacture of the hose.

Experiments were conducted in 1909 and 1910 for the improvement of solid-stream nozzles, and resulted in the production of a nozzle that gave much more satisfaction, gaining at least 25 feet in the height of the stream, working at the same pressure, with the same size tip, and using the same amount of solution. Later it was observed that some means should be devised for breaking the force of the stream, so that small trees and the lower foliage of large trees could be properly sprayed. For this purpose a strip of brass, slightly curved, about 10 inches long and 1¼ inches wide, known as a spreader, was attached to a brass ferrule about a foot in length, so that it could be moved up and down the tube of the nozzle. When this brass strip is slid beyond the tip the force of the solution coming in contact with it is broken up into a fan-shaped stream, thus giving a good mist spray. (Pl. V, *b*, *c*.)

Solid-stream nozzles now being used have a full-way shut-off at the hose end which is packed on both sides to prevent leakage, and a reduction is made in the condensing head for a tapered way of approximately 1 inch in length. The "hopkins" is placed directly in the end of the tube, straightening the stream practically at the tip entrance. The tips are all bored from solid metal, making an absolutely smooth waterway. A swiveled handle is provided on the large nozzles to permit them to turn freely when the hose twists, without annoyance to the nozzleman. The introduction of this nozzle practically eliminated the climbing of forest trees in spraying. For full details of construction, see Plate VI.

MOTOR-TRUCK SPRAYER.[1]

The first motor-truck sprayer used in New England was built in the winter of 1910 along lines suggested by the writer. This sprayer was used by the State of Massachusetts and gave such satisfactory results that several others have been built and are being used in that State. (Pl. I.)

In the fall of 1915 a machine of this type was built for the Bureau of Entomology and has been used to great advantage during the past summer.

Profiting by the experience secured when the other machines were constructed, the one built for the Bureau was improved and perfected in many respects, so as to render its operation more perfect and economical. A machine of this type is particularly useful where work has to be done in locations demanding the use of long lines of hose and where water must be hauled long distances. It can accomplish more work in a single season than four horse-drawn high-power sprayers and can be operated more economically on account of saving time on the road and reduction in the number of men needed.

One and one-eighth inch hose is used on this machine, as it does not offer as much resistance as the hose of smaller diameter, and makes it possible to maintain proper pressures at the nozzle when 2,500 feet of hose is required. Two automatic safety release valves are connected to the pump, one set at 300 pounds and one at 500 pounds. The maximum pressure needed on 2,500 feet of 1⅛-inch hose to obtain 225 pounds at the nozzle is 475 pounds, against approximately 600 pounds in the case of 1-inch hose.

When 1-inch hose is used the pressure must be increased 50 pounds for every 100 feet that the nozzle is operated above the level of the sprayer. With 1⅛-inch hose a slightly greater pressure is required. This matter must be given careful attention when lines of hose are run to hilltop areas which are at much greater elevations than the sprayer.

When the sprayer truck combination is not in use the pump and tank attachment can be easily removed and a commercial body attached which can be used in transporting supplies to and from the field. (Pl. VII.)

The construction of the motor-truck sprayer is of special design, owing to the double work which it is called upon to perform. As the truck must propel itself and at the same time maintain high pressure for spraying, it is necessary to have an engine transmission of extra strength, and many other parts are oversize from what would be necessary for an ordinary 3-ton truck. The chassis is of 1-inch beam construction, with platform springs and chain drive. The engine is 45–60 horsepower and has an internal governor. It has three speeds forward and one reverse, with special transfer arrangement to the pump which makes it possible to spray while traveling or standing. The controls for operating either the truck or spraying attachment are easily reached from the driver's seat. The pump is practically the same as those on horse-drawn outfits, with the exception that it is reinforced in many places to stand extra high pressures. The tank is of the U-shaped type, with a 400-gallon capacity.

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[1] Since this manuscript was prepared a more powerful truck sprayer has been designed. For this purpose a 5-ton truck with a worm drive and a pump of greater capacity has been used. This outfit is to be used in difficult spraying work in the border territory of the gipsy moth infested region.

In doing street-tree or roadside spraying, the motor truck is especially adapted, as very little time is wasted in securing water.

POISON.

The amount of poison to be used varies with different insects, as some species will withstand more than others. In the case of the apple-tree tent caterpillar (*Malacosoma americana* Fab.) about one-half the amount of poison is required that is necessary to kill the gipsy-moth caterpillars. It is obviously wasteful to use an unnecessary amount of poison. In the case of the gipsy moth, 10 pounds of arsenate of lead and 100 gallons of water is sufficient until the caterpillars have passed the third stage; then the poison should be increased to 12½ pounds to 100 gallons of water. This increase is necessary, as the caterpillars are more resistant to poison as they grow older.

Spraying against any leaf-eating larva at the time when it is about to change to the pupal stage is not as a rule satsifactory, as very little feeding is done for a few days previous to transforming.

In purchasing arsenate of lead paste, the following specifications have been found satisfactory:

Fifty per cent actual dry arsenate of lead, not less than 15 per cent arsenic oxid (As_2O_5), not more than three-fourths of 1 per cent of soluble arsenates, no free acids, no adulterant or inert substances. Arsenate of lead should be in a good mechanical and physical condition and should be subjected to analysis.

These specifications carry 3 per cent more arsenic oxide (As_2O_5) than is required by Federal law, but much better work is done than by the weaker percentage and with more economy.

Poison carried over from one season to another in wooden containers should be tested before it is used to ascertain if it contains the proper amount of moisture, otherwise a larger amount of actual arsenate of lead may be used than is necessary.

Dry arsenate of lead has been tried on a small scale and has given good results. It has not been used extensively, as it is more expensive than the paste form.

MIXING POISON.

Arsenate of lead in paste form can be obtained in different-size steel drums or wooden packages, and should contain 50 per cent water. The lead, being heavier than the water, readily settles at the bottom of the container and should be stirred to an even consistency before being mixed with water for spraying. If this is not properly done an uneven strength of the solution is the result and consequently spraying operations are often unsatisfactory. This is one of the parts of a spraying operation that is easiest to neglect, and in order to secure an even solution a mixer has been devised, as shown in Plate VIII. It can be attached to a 100-pound drum of arsenate of lead and the contents brought to an even consistency in from 3 to 5 minutes. The lead should be poured into another drum to make sure it is thoroughly mixed, thus increasing its efficiency and lessening the cost of labor.

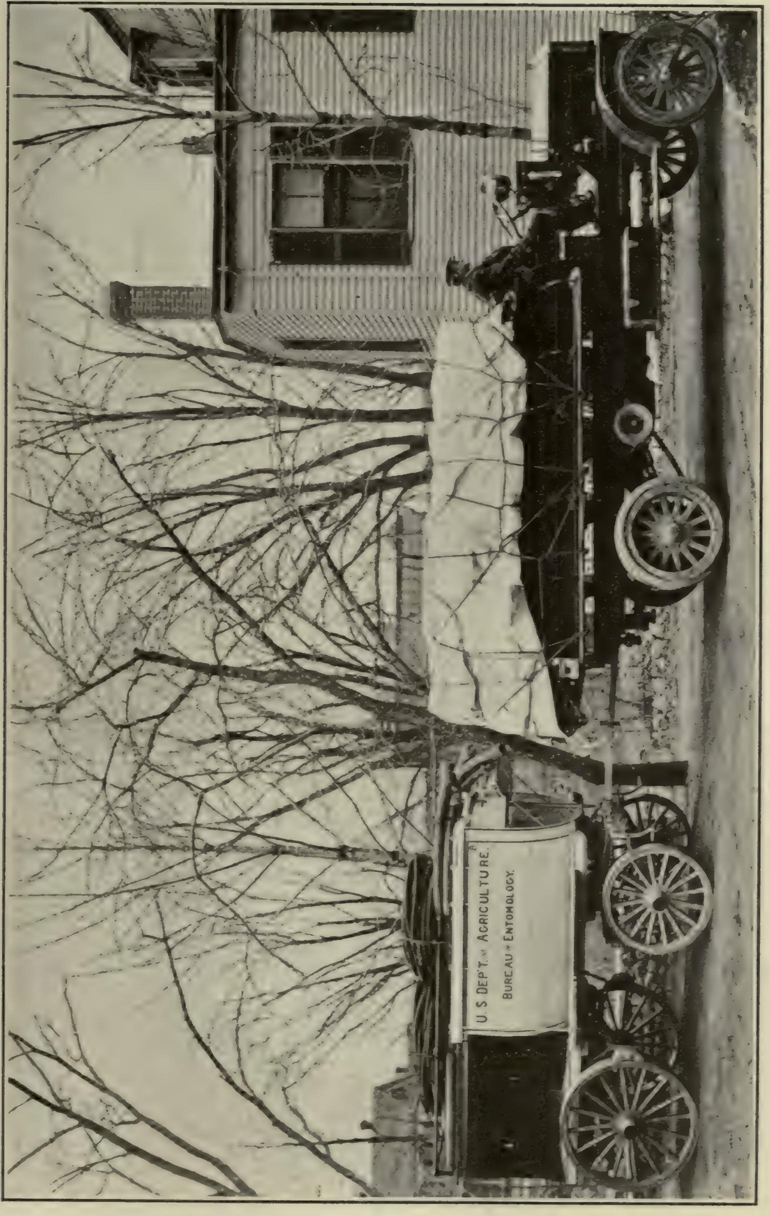
AGITATION.

Agitation is one of the most important factors in the operation of any spraying machine, owing to the fact that if constant and thorough agitation is not maintained uneven results may be expected. In some power machines the agitator is in motion only when the pump is working, but this is not a satisfactory arrangement. If the machine is moved from one location to another and the pump is stopped a large part of the poison will settle to the bottom of the tank. It is very difficult to get arsenate of lead again into suspension, under such conditions, as it has to be sucked gradually from the bottom of the tank by the agitator, which will not function as well as if the poison is not allowed to settle.

On all machines the agitator should be directly connected with the engine and when the pump is not in use the engine should be run slowly, so as to keep the solution well mixed until the tank is empty.

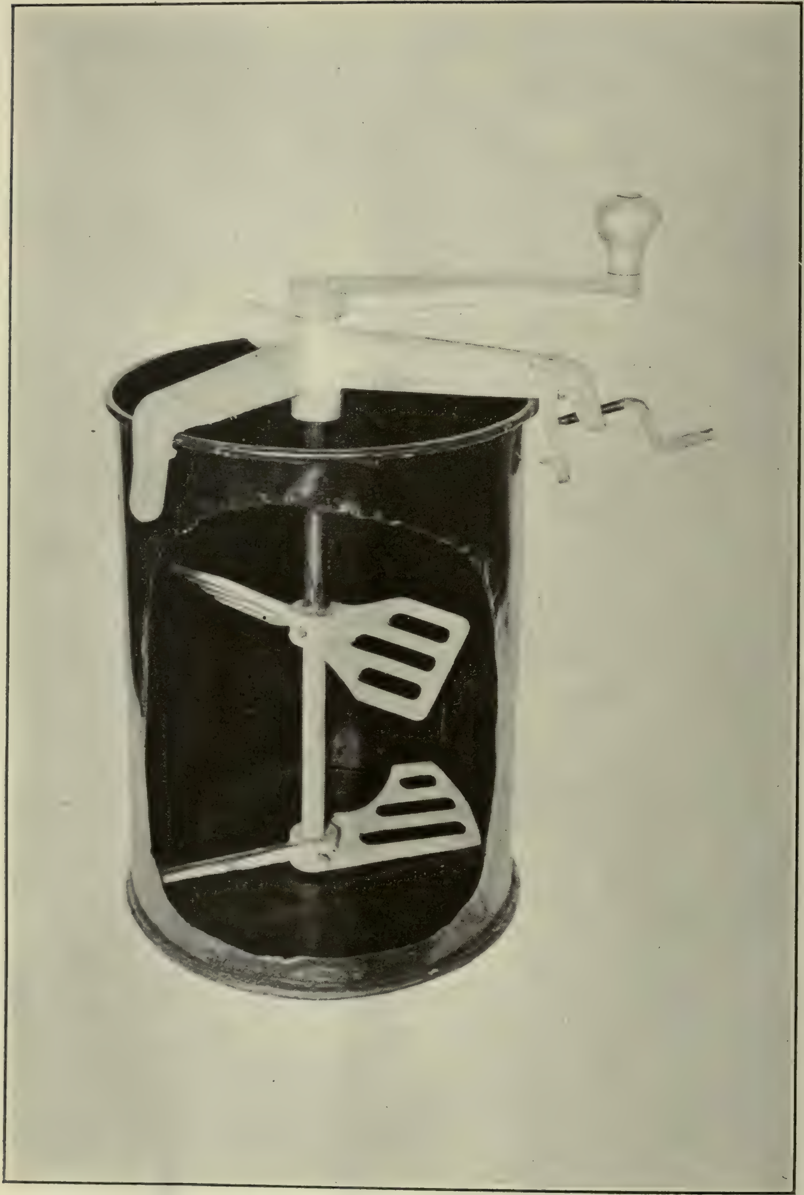
AMOUNT OF SOLUTION TO BE USED.

The amount of solution used in solid-stream spraying should be carefully guarded, as it is very easy for considerable waste to occur. With high-power outfits using 1-inch hose and one-fourth-inch tip on the nozzle, from 25 to 35 gallons of solution is being delivered



THE MOTOR TRUCK AND PRESENT-DAY METHODS.

Motor truck used for hauling supplies and spraying outfit. Total load, four tons.



AN IMPROVED TYPE OF POISON MIXER.

Poison mixer attached to 100-pound drum, showing paddles.

every minute, and as the average shade tree contains about 3,000 square feet of foliage and 9½ gallons of solution will actually cover this amount of foliage, it is practically impossible to prevent a small amount of waste, although a much smaller percentage than would be supposed results if care is taken by the nozzleman. One-half minute of solid-stream spraying at the proper pressure will ordinarily spray the average shade tree.

There are several conditions which would cause this estimate to vary, such as high winds, location of tree, etc. In directing solid-stream spray, the force of the stream should never be allowed to strike the foliage, as the solution will not adhere, but is driven off. It should be applied in as near a mist form as possible. In the spraying of shade trees care should be taken to direct the stream so that the mist will blow or drift through the foliage. It is not always possible to spray all sides of a tree, but it can usually be completely sprayed by drifting it through or by allowing the stream to go over the tree. In spraying trees on country roadsides, where the water supply is not always easy of access, considerable time can be saved by filling the tank when there is an opportunity, even if it is not empty. If this is done an accurate method should be worked out to determine the amount of water to be added so that the proper weight of poison can be placed in the tank. Considerable time is required to secure water, even if hydrants are available.

PRESSURES.

A knowledge of the correct pressures to use in solid-stream spraying is most essential. As has been previously stated, the solution should reach the leaves as a mist if best results are to be obtained. If this is not done much poison is wasted, and if the force of the stream is allowed to come in direct contact with the foliage it often tears and damages the leaves.

After several years experience and many experiments, it has been concluded that to obtain the best results the pressure at the nozzle when 1-inch hose is used with any sized tip should be 225 pounds in order to break the stream into a mist at the proper place.

It has been determined by tests shown in Table I that it is not practical to use over 1,500 feet of 1-inch hose with the high-power machine when a one-fourth-inch tip is used. and not over 600 feet of 1-inch hose when a five-sixteenths-inch tip is used.

TABLE I.—*Correct nozzle pressures for different lengths of hose and sizes of tips.*

Length of hose.	Nozzle pressure.	Pressure at the machine.			
		One-eighth inch.	Three-sixteenths inch.	One-fourth inch.	Five-sixteenths inch.
Feet.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
100	225	225	225	240	250
200	225	225	225+	250	275
300	225	225	230	260+	300
400	225	225	240−	275+	325
500	225	225	250−	290−	350
600	225	225	250	305−	400−
700	225	230	255	310+	....
800	225	230+	260	320	....
900	225	235	265	330	....
1,000	225	235+	268	340	....
1,100	225	240−	270	350	....
1,200	225	240	272	360	....
1,300	225	240+	275	370+	....
1,400	225	240+	278	390−	....
1,500	225	245−	280	410	....

The tables submitted are actual readings taken in the field, and the nearest to a 5-pound point was taken. Some of the variations can only be explained by the expansion of the rubber hose, which also explains the difference from the friction loss in 1-inch iron pipe.[1]

EXPERIMENT TO DETERMINE THE DISTRIBUTION OF POISON ON FOLIAGE.

In order to determine how thoroughly trees were being sprayed by using the solid-stream method a number of experiments were conducted during the summer of 1916.

For this purpose a series of ferrotype plates, 14 by 10 inches, were secured and treated with black coach paint so that any spray coming in contact with them could be seen. The plates were numbered and attached to bamboo poles about 12 feet in length. This was done by splitting the small end of the pole, and after inserting the plate it was sewed in place securely with copper wire.

The plates were then placed in different positions and at different heights in trees that were to be sprayed and a record secured of the effectiveness of the work. (Pl. IX.) This is a method that can be used by anyone to test the thoroughness of spraying for leaf-eating insects.

One test was conducted to determine the time required properly to spray a shade tree when the solid-stream method is used. The tree selected was 65 feet in height, and excellent results were secured by applying the spray for half a minute. A glance at Plates X and XI shows the thoroughness of the treatment in this test and illustrates the value of this method of spraying when properly used.

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[1] See Engineering Work in Towns and Small Cities, by Ernest McCullough, 1906, p. 359. Pumping Machinery, by William M. Barr, 1908, p. 108.

SHADE-TREE SPRAYING.

The spraying of shade trees with arsenate of lead should be accomplished at as early a date as possible after the foliage has sufficiently developed. (Pl. XII.) Early spraying not only applies to the gipsy moth, but will poison many brown-tail caterpillars, as they are much earlier feeders than the gipsy moth. In the case of the elm leaf-beetle (*Galerucella luteola* Müll.) much is accomplished in poisoning the adult beetles, which do a small amount of feeding after coming out of hibernation before mating and laying eggs, as they are very easily poisoned at that time. It is often argued that solid-stream spraying on street trees is too expensive and that the work can be done much cheaper with smaller apparatus. The principal reason for this is because of the low first cost of the smaller outfits. (Pl. XIII.) This may be true for a single year, but for two or more years the solid-stream method is the cheaper. The total cost of the most expensive high-power apparatus on the market at the present time is approximately $1,500 for a complete equipment. It is safe to figure depreciation at the rate of 20 per cent each year, although there are machines in the field at the present time that have been used 8 years and have only required an annual overhauling and the replacement of small worn parts. In 20 days' spraying one large machine should treat 10,000 shade trees. This would average only 3 cents for each tree in depreciation which is not prohibitive to any municipality. Taking everything into consideration, the entire cost of spraying shade trees with the solid stream does not exceed 12 cents per tree if the work is managed properly. The following figures are submitted to show how the cost per day is computed for 20 working days:

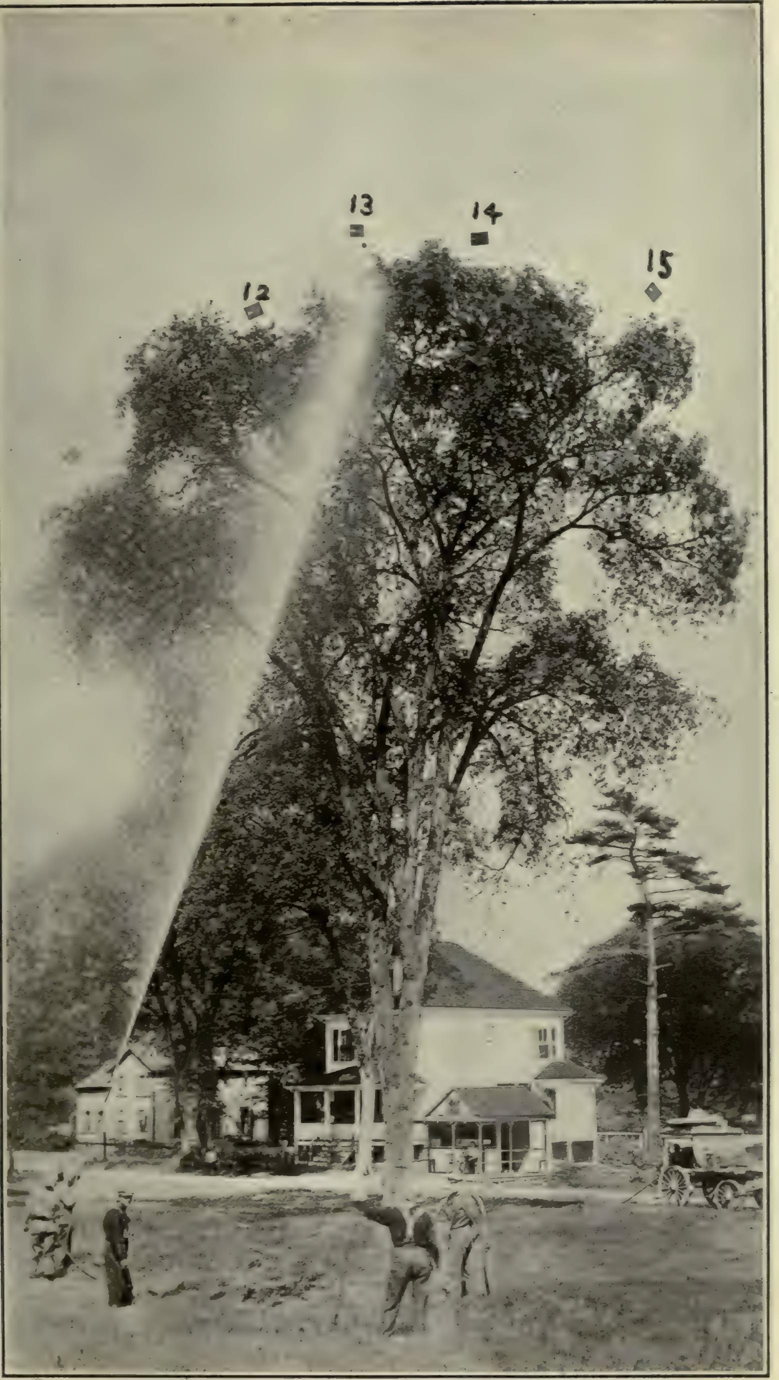
1 pair of horses and driver	$6.00
3 men, 8 hours each	7.50
560 pounds of poison, at 5 cents per pound	28.00
10 gallons of gasoline	1.80
1 gallon of oil	.30
Depreciation per day at 20 per cent per year	15.00
	$58.60

The average number of shade trees sprayed with each 400 gallons of poison is 35, and 14 tanks (5,600 gallons) in 8 hours is a good average, totaling 490 street trees per day, making the average cost per tree about 11¾ cents. In treating shade trees, where any considerable amount of spraying is to be done, the use of small outfits in mist spraying is much more expensive than the solid-stream method. In an experiment conducted during the summer of 1916 the cost of treatment with a small hand outfit was more than twice the amount per tree that it was when the solid stream was used. While one can find considerable variation in the cost of applying the mist spray, either with gasoline or hand outfits, it is more than double the cost of solid-stream spraying, which, in the long run of the season's work, will equal an amount that will more than two-thirds pay for a high-grade solid-stream machine and equipment. By following the mist method for two seasons a high-grade outfit has practically been thrown away and with no asset shown for money expended.

WOODLAND SPRAYING.

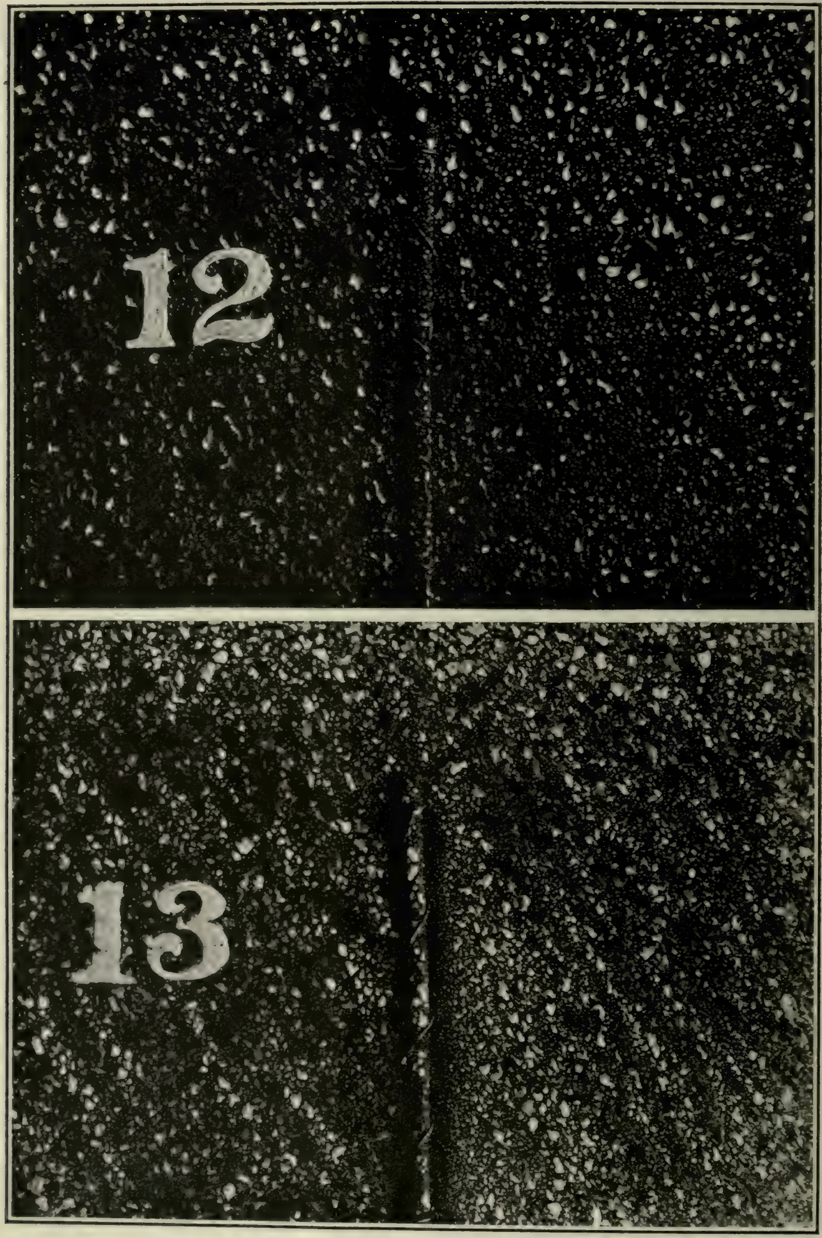
In woodland or park spraying the solid-stream method is in a class by itself, as the climbing of trees over large areas makes the mist method not only too slow but laborious and expensive. With a high-grade solid-stream machine properly equipped an average of from 12 to 15 acres can be sprayed in a day. This applies to large areas where machines can be operated without the necessity of moving any great distance in the day's work. Twenty-one acres of woodland, consisting mostly of trees 60 to 70 feet high, is the maximum treated in a single day. (Pl. XIV.) In this instance the water supply was convenient and easily accessible. The solid-stream machine for woodland spraying should be equipped with from 1,000 to 1,500 feet of 1-inch hose; 100 feet of 2½-inch suction hose, suction strainer, two nozzles (one long and one short), and with each nozzle one of the following tips: $\frac{5}{16}$, $\frac{1}{4}$, $\frac{3}{16}$, $\frac{1}{8}$ inch bores. The nozzles should be equipped with a brass spreader for spraying undergrowth and low foliage. (Pl. XV.) Hose should be provided with couplings that will not blow out—if expensive delays are to be avoided. Spraying in woodland should be arranged so that whenever possible the location of the hose may be changed while the sprayer is being filled. Much time will be lost if this is not done, and 10 men are usually necessary where long lines of hose are being used.

Men should be so located on hose lines that the nozzlemen will not be hindered by the weight of hose. The number of men needed in woodland spraying is determined entirely by the lengths of hose used. One hundred feet of 1-inch 8-ply cotton-covered hose weighs 84 pounds, and carries 4.8 gallons of water weighing 32.64 pounds, making the total weight when spraying 116.64 pounds. This makes it necessary to assign a man to every 100 feet, besides the nozzleman. The cost of woodland spraying where large areas are involved averages about $5.50 per acre. Where only small areas are sprayed the cost is much greater. Six hundred gallons of solution, when properly applied, will usually spray an acre and no climbing should be necessary. In experiments recently conducted, a pine tree 99½ feet high was successfully sprayed from the ground. Good results can usually be obtained in woodland spraying by directing the stream through the open places in the foliage in order to minimize damage



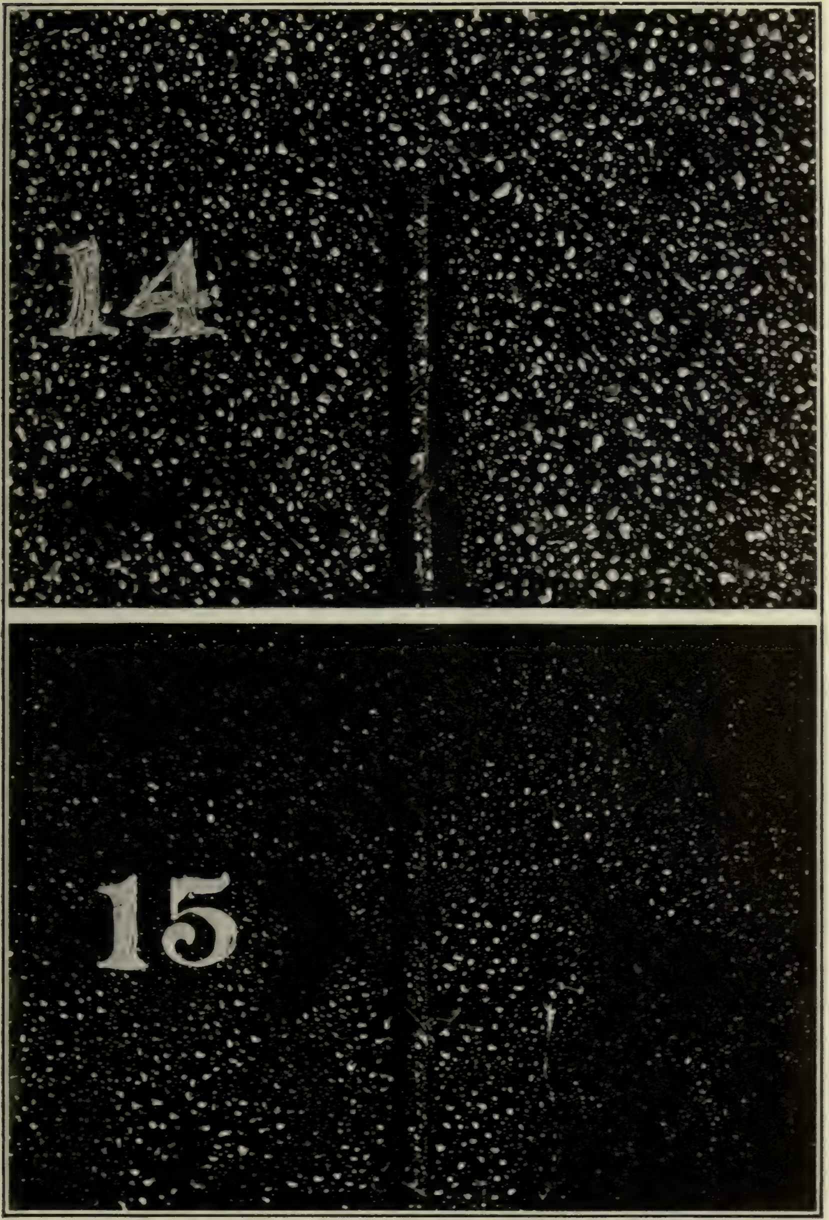
TESTING THE DISTRIBUTION OF POISON SPRAY.

Spraying elm tree 65 feet high with solid stream. Note the plates at top of tree which were used to secure a record of the distribution of the poison. (Original.)



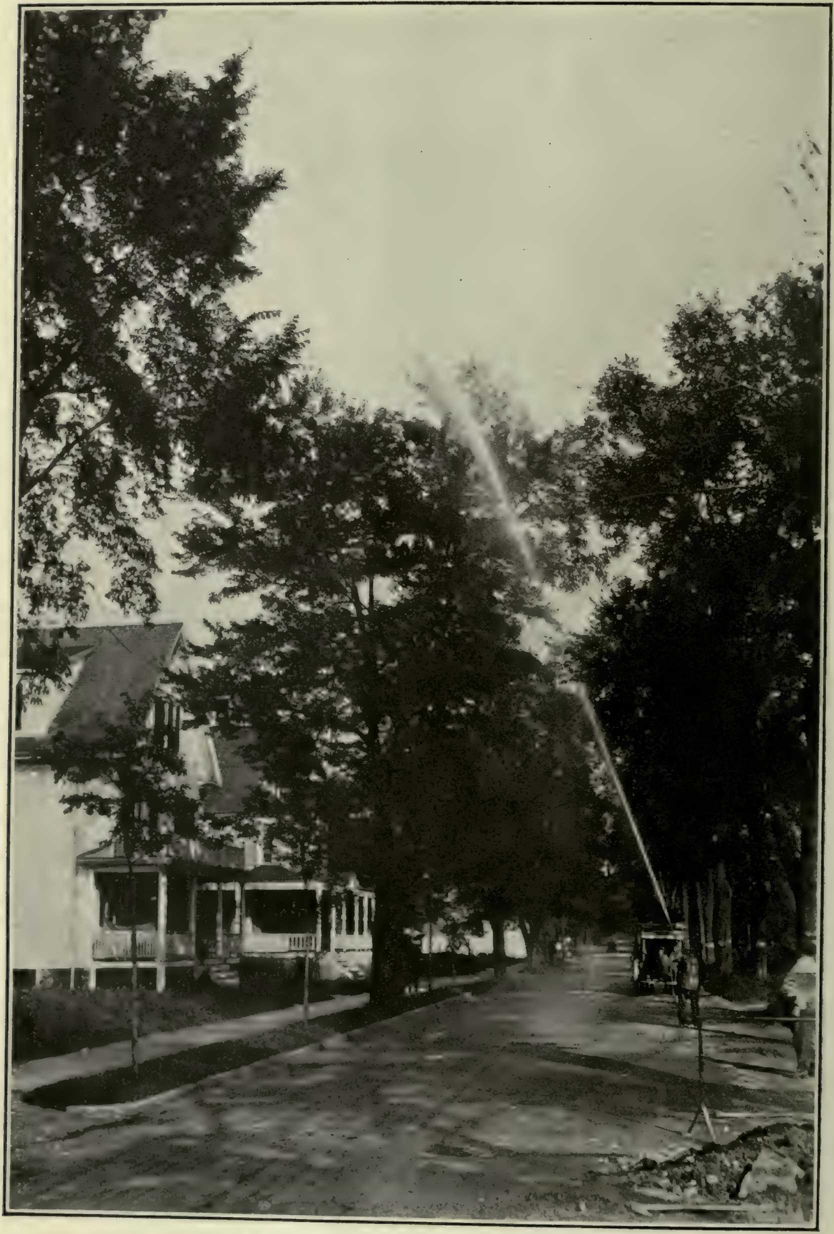
RESULTS OF TESTS FOR DISTRIBUTION OF POISON SPRAY.

Distribution of poison. Location of these plates is shown in Plate IX. (Original.)



RESULTS OF TESTS FOR DISTRIBUTION OF POISON SPRAY.

Distribution of poison. Location of these plates is shown in Plate IX. (Original.)

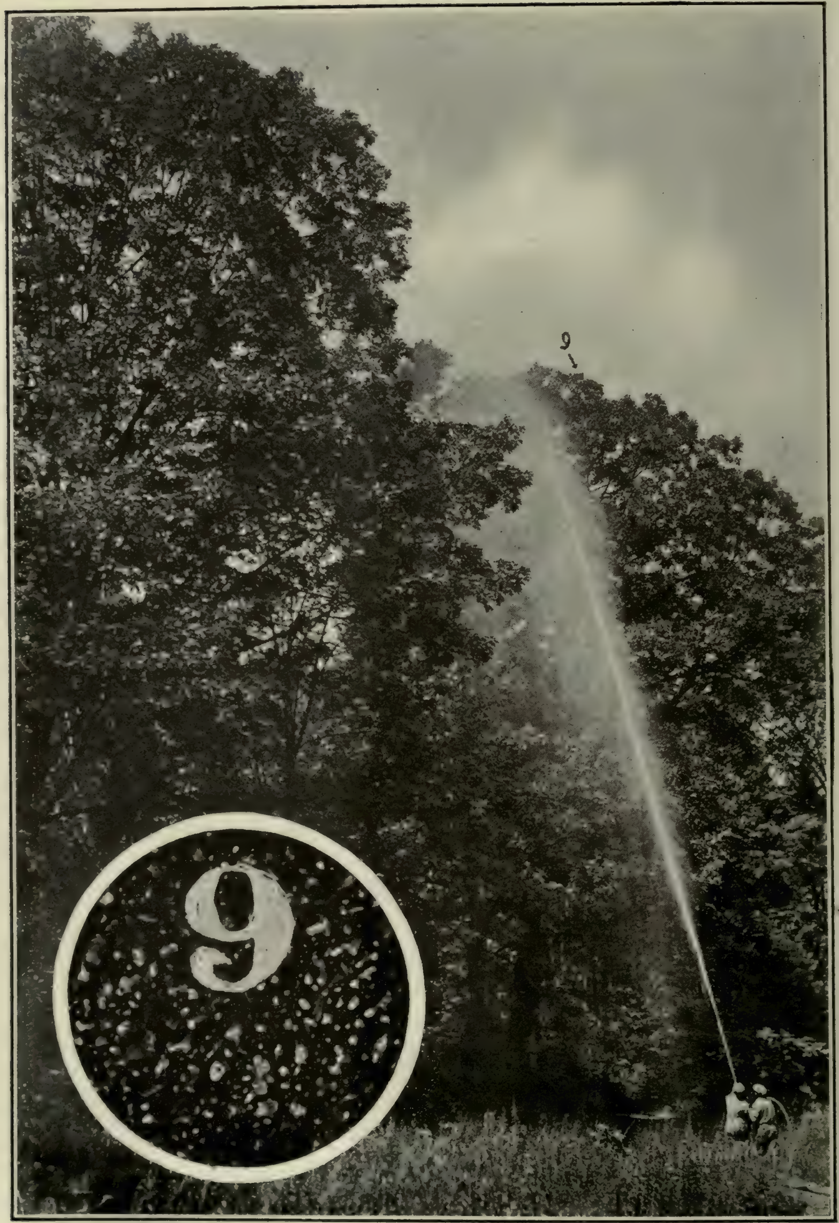


THE SOLID-STREAM SPRAYER IN OPERATION.

Spraying shade trees along the streets with solid stream. (Original.)

THE UNSATISFACTORY, OLD-TIME SPRAYING OPERATION WITH A HAND OUTFIT.

Spraying shade trees with hand outfit. These trees had to be climbed in order to treat the tops. (Original.)



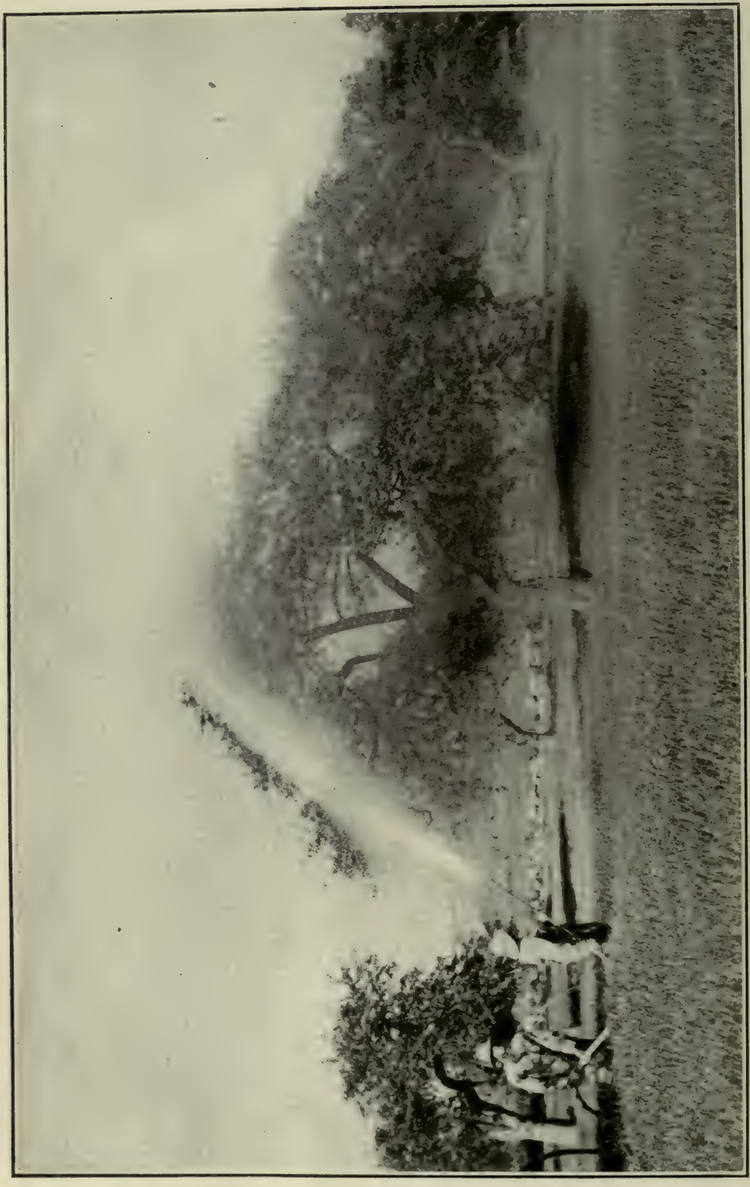
TESTS FOR DISTRIBUTION OF POISONED SPRAY AT EXTREME HEIGHTS.

Spraying oak 85 feet high in woodland. Note the distribution of the poison spray on the plate located at top of tree. (Original.)

ADAPTATION OF THE SPREADER IN SPRAYING OPERATIONS.

Spraying low growth, using spreader. (Original.)

PLATE XVI.



ADAPTATION OF SPREADER TO ORCHARD-SPRAYING OPERATIONS.

Spraying orchard with solid stream, using spreader. (Original.)

to the leaves, and at the same time thoroughly treat the surrounding foliage. By using a spreader on the nozzles the lower foliage and undergrowth can be properly sprayed with much less damage or loss of solution than if the solid stream is applied. The essential thing in woodland spraying is to keep the nozzleman moving. Poison is sure to be wasted when stops are made for any length of time. Careful arrangements for water supply should be made in advance. Damming of brooks or digging holes in low ground to provide an accumulation of water will reduce the cost of spraying to a great extent. It sometimes becomes advisable in the spraying of large wooded areas to build temporary roads. This is often necessary from an economic standpoint, as the average wood road suitable for spraying machines can be built for 5 cents per square yard, and results in a great saving in the aggregate spraying cost. Especial care should be taken in the spraying of conifers, as the leaf area is very small and the stream must be broken into a fine mist in order to have the solution adhere.

WINTER CARE OF SPRAYING MACHINES AND EQUIPMENT.

Failure to take proper care of a spraying outfit is responsible for most of the difficulties and delays that result during the spraying season. This is particularly true in regard to the precautions that should be taken when the spraying season is over and the machine is laid up for the winter. If careful attention is not given to the apparatus at this time, many difficulties and delays are likely to result during the following season.

Each machine should be taken to a convenient water supply and clear water forced through the pump and hose until both are perfectly clean. The running gear should be thoroughly washed. After this has been done the hose should be laid away for the winter. Storing hose in coils should be avoided. The machine should be properly drained of water and all metal parts coated with heavy grease. Care should be taken that all valves and petcocks are open, and the plugs and packing in the pump should be removed for the winter to allow the latter to drain. After the water has been properly drained from the engine and the circulating pipes have been disconnected the engine should be started and run for a few minutes so as to force the water out of the pump and check valves into the water jacket of the engine, where the heat will cause it to evaporate. Care should be taken not to allow the engine to become overheated while being run under the above conditions. After this has been done the spark plugs should be removed and wrapped in oiled cloth to prevent rusting. After the spark plugs have been removed, pour a cupful of cylinder oil into each cylinder and turn the engine over a few times, so that the oil may be worked in around the piston rings. Cork stoppers should be placed in the spark-plug holes to prevent moisture from entering the cylinders. The panels should be taken from both sides of the engine and all oil removed from crank case, after which the crank shaft and connecting rods should be coated with heavy grease. A few drops of light oil should be worked into all metal parts of the magneto bearing to prevent rusting.

SUMMARY.

The subject of spraying, either solid-stream or mist spray, should be given very careful consideration, as the importance of securing good results is imperative. If they are accomplished, much more interest and cooperation may be expected in the problem of controlling leaf-eating insects. It often happens that those responsible for the results do not give sufficient attention to important details until it is too late in the season to secure the best results. One should familiarize himself with every phase of spraying, so that he may be able to cope with all conditions. While there are still those at the present time who do not feel that solid-stream spraying with arsenate of lead can be as effective as that done with smaller machines and mist nozzles, all will concede that much good work has been accomplished in the gipsy-moth area in New England with solid-stream spraying. While the solid-stream method is confined almost entirely to shade-tree and forest spraying it has been used successfully in orchards (Pl. XVI). Solid-stream work is not necessarily confined to the highest-power machines, as good results may be obtained on a small scale with medium-power machines capable of delivering a solid stream of smaller size, and which at the same time may be easily converted to mist-spray work. This also applies to the larger machines.

The problem of fighting the gipsy moth and the brown-tail moth is of such magnitude and general economic importance that it would be impossible to do the necessary spraying in the infested area with mist spray and small machines. During part of many seasons the weather is not suitable for spraying, and when conditions are right a large amount of spraying must be accomplished in a short time. The work of several boring insects which have riddled our shade trees in the past few years has also made climbing of them much more hazardous, but this must be done if the mist spray is used. If climbing is resorted to, the expense is prohibitive, especially in wooded areas.

Many times the question is asked, "Why pursue other methods of fighting the gipsy moth and the brown-tail moth; why not confine it entirely to spraying?" There are several reasons; the nature and severity of the infestation must be taken into consideration, and the proximity and danger of spread to noninfested regions. If extermination is to be expected it would not be wise to confine all efforts to spraying. If the infestation is severe and egg clusters are very numerous they should be treated with creosote prior to spraying. What is termed "rough creosoting" consists of treating the egg clusters, which can be easily reached in areas to be sprayed. In rare cases infested shade trees are located near buildings where it is impossible to spray without defacing the buildings to some extent. This can be avoided, however, if buildings are first wet with clear water. If the infestations are located in pasture lands, proper precaution should be exercised so that live stock will not be poisoned. Poison notices should be placed in conspicuous places in all locations where spraying is done.

From 800 to 1,000 tons of arsenate of lead and about 500 high-power solid-stream machines are being used each year in the New England States in fighting the gipsy moth. Thousands of acres of park and orchard trees and woodland in addition to approximately 20,000 miles of street trees are being sprayed. When spraying is properly done to control the gipsy moth, very little trouble is experienced with other leaf-eating insects.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO THE GIPSY MOTH AND THE BROWN-TAIL MOTH.

AVAILABLE FOR FREE DISTRIBUTION.

The Gipsy Moth and the Brown-tail Moth, with Suggestions for their Control. (Farmers' Bulletin 564.)

Report on the Gipsy Moth Work in New England. (Department Bulletin 204.)

Control of the Gipsy Moth by Forest Management. (Department Bulletin 484.)

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Food Plants of the Gipsy Moth in America. (Department Bulletin 250.) Price, 10 cents.

The Calosoma Beetle in New England. (Department Bulletin 251.) Price, 15 cents.

Dispersion of Gipsy Moth Larvæ by the Wind. (Department Bulletin 273.) Price, 15 cents.

The Gipsy Moth as a Forest Insect. (Entomology Circular 164.) Price, 5 cents.

The Gipsy Moth in America: An Account of the Introduction and Spread of Porthetria Dispar in Massachusetts and of Efforts made by the State to Repress and Exterminate It. (Entomology Bulletin 11, n. s.) Price, 5 cents.

Report on Field Work Against the Gipsy Moth and the Brown-tail Moth. (Entomology Bulletin 87.) Price, 35 cents.

Importation Into the United States of Parasites of the Gipsy Moth and the Brown-tail Moth: A Report of Progress, with Some Considerations of Previous and Concurrent Efforts of this Kind. (Entomology Bulletin 91.) Price, 65 cents.

Calosoma Sycophanta, Its Life History, Behavior, and Successful Colonization in New England. (Entomology Bulletin 101.) Price, 25 cents.

The Dispersion of the Gipsy Moth. (Entomology Bulletin 119.) Price, 20 cents.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 598

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER. February 4, 1918

ORCHARD INJURY BY THE HICKORY TIGER-MOTH.

By DWIGHT ISELY, *Scientific Assistant, Deciduous Fruit Insect Investigations.*

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INTRODUCTION.

The injurious stage of the hickory tiger-moth, *Halisidota caryae* Harris,[1] is a gregarious summer caterpillar (Pls. I, II) which, although a general feeder on deciduous trees and shrubs, causes occasional injury in orchards of pomaceous fruits and cultivated walnuts. While in this respect it is a minor pest, its injury, where it occurs, is severe and conspicuous and is the source of frequent inquiries to the Bureau of Entomology and to entomologists in the field. The writer's attention was frequently called to the work of this caterpillar while stationed at North East, Pa., during the seasons of 1914, 1915, and 1916, and there, incidental to the major projects then under investigation, the seasonal history and habits of this insect have been studied and the necessary remedial measures determined.[2]

HISTORY.

Injury by the hickory tiger-moth was first described by Harris in 1841 (1) in the earliest important work on economic entomology published in America. Since then frequent reports of local outbreaks have been recorded in entomological literature. Complaints have been made to the Bureau of Entomology regularly since 1870, and specimens and records of injury have been received annually since 1904. Yet in spite of this constant occurrence there appear to be no records of very great destructiveness. The nearest approach to a general outbreak recorded occurred in 1907, when the bureau received numerous complaints from New England as well as scattered reports from other parts of the United States and from Canada. When Harris (1)[1] first described the adult, larva, and pupa as *Lophocampa caryae*, he gave in addition a brief account of the larval feeding and cocoon-making habits, and listed hickory, elm, and ash as food plants. Fitch (2) in 1855 gave a further account of larval habits and added butternut, sumach, and slippery elm to Harris's list of food plants; and during this same year the species was listed by Walker (3) and figured by Herrich-Schäffer (4). In 1882 it was listed by Grote (5). Few biological data were added until Beutenmüller (6) in 1890 listed 32 food plants of the hickory tiger-moth. The same year Dyar (7), in discussing head measurements of lepidopterous larvæ, recorded nine larva stages of *H. caryae*. Soule (8) in 1891 first described the egg and gave life-history records from egg to pupa, but recorded only seven larva stages. Packard (9) in 1893 also described the egg and larva stages and of the latter recorded only five. Eliot and Soule (11) in 1902 gave a popular account of the life history similar to the previous one by the junior author, and this later account is the most nearly complete record of its biology.

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[1] Order Lepidoptera, family Arctiidae.

[2] The writer was assisted in 1915 by E. R. Selkregg and in 1916 by James K. Primm.

From 1905 to 1908, inclusive, the period when inquiries made to the Bureau of Entomology regarding this insect were most frequent, there were a number of brief references to it by economic entomologists in the northeastern United States. These references were brief and added little to the published records except to note its economic importance. Patch (12) mentions it as a late summer feeder, Felt (13 and 15) records it as of economic importance in New York, Sanderson (14 and 19) records it among apple insects of New Hampshire, Britton (16) refers to it as abundant in Connecticut, and Gibson (17) records an unusual outbreak for two years in several Canadian Provinces. Dr. L. O. Howard states that this species was unusually abundant in Greene County, N. Y., in September, 1917.

COMMON NAME.

This insect was called the hickory tussock moth by Harris (1), and until a comparatively recent time this name has been used. Comstock (10) called it the hickory tiger-moth. The latter name would seem preferable, since the insect belongs to the family of tiger-moths (Arctiidae) and not to the family of tussock moths (Lymantriidae).

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[1] Reference is made by number to "Literature cited," p. 13.

SYNONYMY.

Lophocampa caryae Harris, 1841.
Halesidota annulifacia Walker, 1855.
Phegoptera porphyrea Herrich-Schäffer, 1855.
Halisidota caryae (Harris) Grote, 1882.
Halisidota caryae (Harris) *Packard*, 1890.

DISTRIBUTION.

The hickory tiger-moth is distributed over the northeastern United States and the adjacent Canadian Provinces. According to records of the Bureau of Entomology and literature, its range extends from the Atlantic Ocean west to Missouri, Minnesota, and Saskatchewan, and from the Canadian Provinces bordering the United States south to North Carolina and southern Ohio. Records have been taken from the following States and Canadian Provinces: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, New York, Pennsylvania, New Jersey, North Carolina, Ohio, Michigan, Illinois, Wisconsin, Missouri, Quebec, Ontario, Manitoba, and Saskatchewan. It is probably much more frequent in New England and the Middle States, however, since more than 75 per cent of the reports of destructiveness have come from this region.

DESCRIPTION OF STAGES.

EGG.

(Pl. II, fig. 4.)

The egg is nearly globular, flattened on the side of attachment, 0.75 mm. in diameter. The surface is glassy and in color it is a robin's-egg blue when first deposited. A brown ring appears on the upper surface about the second day, and in a few days the egg appears olive brown when viewed from above, although when viewed from the side it is greenish. In about two weeks, just before hatching, it becomes leaden blue. Infertile eggs do not change in color, but dry up in a few weeks. Eggs are deposited in a broad patch of 50 to 400 on the underside of the leaf. The writer has found one patch of 525 eggs.

LARVA.

(Pl. I, Pl. II, figs. 1, 2, 3.)

Full-grown larva.—Length, 32 to 38 mm. A striking grayish-white and black hairy caterpillar. It is covered with short spreading tufts of grayish white hairs, with a dorsal row of contiguous black tufts which appear like a velvety crest. These tufts occur on the first eight abdominal segments and a small one may be seen on the ninth. There also may be a pair of slender black pencils arising from the first abdominal segment, and another pair arising from the seventh. These pencils may be very long, may be inconspicuous, or absent altogether. The head and feet are black. The hair arising from the thoracic segments is longer than that of the rest of the body and when the larva is at rest covers the head. The spreading side tufts give the larva a depressed appearance.

First instar (Pl. II, fig. 1).—Width of head, 0.46 to 0.50 mm; total length 1.5 mm.; when full fed, 3 mm. The head is shining black and is much wider than the thorax of a newly hatched larva. The body is cylindrical, pale greenish white, and marked with black setiferous tubercles. Dorsally the tubercles appear as follows: On the first thoracic segment, a large dorsal plate and two very small tubercles on either side; second thoracic segment, one large compound tubercle on either side near the cephalic margin and a very small median tubercle near the caudal margin; third thoracic segment, 2 conspicuous tubercles on either side; first to eighth abdominal segments, 3 conspicuous tubercles on either side arranged in a triangle, two of them being near the cephalic and one near the caudal margin; ninth abdominal segment, 1 large compound tubercle on each side; tenth abdominal segment, 1 large plate covering most of the dorsal aspect of the segment. On all the thoracic segments and on third to ninth abdominal segments there are 3 small tubercles on each side; on abdominal segments 1 and 2 there are 4 on each side; and on abdominal segment 10 there is 1 one each side. All the lateral tubercles and lateral-dorsal tubercles bear 1 white seta. Black setæ are all dorsal, 4 arising from each thoracic segment, 1 from each of the 4 median abdominal tubercles, and 6 from the anal plate.

Second instar.—Width of head, 0.65 mm.; total length, 5 to 6 mm. when full fed. This instar differs chiefly from the preceding in the abundance of long whitish hairs which arise in considerable numbers from all the tubercles. The tubercles are larger and contrast strikingly with the color of the body.

Third instar.—Width of head from 1.12 to 1.16 mm.; total length, 10 mm. when full fed. More hairy than the preceding instar.

Fourth instar (Pl. II, fig. 2).—Width of head, 1.7 mm.; total length, 13 to 14 mm. The dorsal tubercles are nearly obscured by the hair arising from them.

Fifth instar.—Width of head, from 1.88 to 2.19 mm., average 2.1 mm.; total length, 18 to 19 mm. Tufts at sides of each body segment becoming conspicuous, and the black pencils may appear in this instar.

Sixth instar.—Width of head, from 2.91 to 3.09 mm., average 3.0 mm.; total length when full fed, 22 to 25 mm. The side tufts have become so conspicuous that they give the larva an almost flattened appearance. The black dorsal tufts are not yet touching and do not yet form a conspicuous crest.

Seventh instar (Pl. II, fig. 3).—Width of head, from 3.43 to 3.52 mm., average 3.46 mm.; total length, 27 to 32 mm. Practically the same as the preceding.

Eighth instar.—Width of head, from 4.10 to 4.30 mm., average 4.2 mm.; total length, 32 to 40 mm. This larva is very much like the preceding if it has yet to pass through another instar, or if this instar is the last it is like the mature larva previously described.

Ninth instar (Pl. I).—Width of head, from 4.7 to 4.9 mm., average 4.8 mm.; total length, 35 to 42 mm. This instar differs conspicuously from the immature forms because of the striking black crest.

COCOON.

(Pl. III, fig. 3.)

The cocoon is usually ellipsoidal, sometimes slightly flattened on one side, depending on the material which surrounds it. In length it averages 23 mm. and in width 15 mm. The larva mixes most of its gray hairs into the silk, making the cocoon very hairy. In color it is dirty gray.

PUPA.

(Pl. III, fig. 2.)

Length, 10 to 13 mm; width of thorax, 6 mm; width of abdomen, 7.5 mm. The abdomen is much stouter than the thorax and there is a slight constriction between them; the wingpads extend to the fifth abdominal segment; on the caudal end is a transverse row of spines recurved at the end. Color when newly transformed, yellowish, but soon becoming reddish brown; margins of segments and spiracles darker.

IMAGO.

(Pl. III, fig. 1.)

The following is Harris's original description of the moth (1):

> * * * very light ochre-yellow in color; the fore-wings are long, rather narrow, and almost pointed, are thickly and finely sprinkled with little brown dots, and have two oblique brownish streaks passing backwards from the front edge, with three rows of white semitransparent spots parallel to the outer hind margin; the hind-wings are very thin, semitransparent, and without spots; and the shoulder covers are edged within with light brown. They expand from one inch and seven-eighths to two inches and a quarter or more. The wings are roofed when at rest, the antennæ are long, with a double narrow, feathery edging, in the males and a double row of short, slender teeth on the under-side, in the females; the feelers are longer than in the other Arctians, and not at all hairy; and the tongue is short but spirally curled.

FOOD PLANTS.

The hickory tiger-moth is usually recorded as a general feeder on the foliage of deciduous trees and shrubs. No less than 49 host plants from widely separated families have been listed by various observers. However, this wide range of food plants is confined to the nearly mature larva. The number of food plants upon which larvæ can develop from egg to pupa is much smaller and, as far as the writer has observed, is restricted to trees of the walnut and hickory family and to pomaceous fruits.

The writer has reared larvæ from egg to pupa on Japanese walnut, English walnut, black walnut, apple, and pear. In the field, colonies have been found frequently on all of the above and also on butternut, quince, and once on white hickory. In spite of its name walnut and not hickory seems to be its favorite food plant. An egg mass was found on a sour-cherry leaf, but a colony of larvæ were never found feeding on cherry in the field. Miss Soule (8) records finding an egg mass on a thorn leaf (*Crataegus* sp.).

The lots of larvæ which were fed on black walnut, Japanese walnut, English walnut, pear, and apple all reached the pupa stage and appeared normal. In the early larva instars the development was about the same. The later instars on Japanese walnut developed somewhat faster than any of the others, and nearly all of them attained the ninth instar before pupation, although those hatching very late passed through only eight instars. Those reared on apple developed more slowly and passed through only eight stages, while the larvæ on pear passed through either eight or nine. The length of stages of larvæ feeding upon these plants will be given in detail in the discussion of seasonal history.

In confinement larvæ would feed on the foliage of many trees upon which they could not mature. Attempts to rear larvæ from hatching to pupation on sour cherry (Early Richmond variety), red oak, and slippery elm were unsuccessful. Those fed on oak and cherry passed through the early molts with regularity, but growth was slower than that of those reared on walnut and apple, and finally stopped altogether. A few larvæ that were started on oak and cherry at the beginning of the second stage reached the seventh, but were undersized and unhealthy in appearance. Elm was more distinctly unfavorable than either oak or cherry. Larvæ placed upon elm immediately after hatching failed to pass even the first molt, and those transferred from walnut as late as the fourth stage failed to pass the seventh.

Table I gives a list of the food plants recorded in entomological literature and in the records of the Bureau of Entomology with the authority for the previously published records. In this list nomenclature of the native species is according to Gray's Manual of Botany, seventh edition (1907), and the nomenclature for imported species is that of Bailey's Standard Cyclopedia of Horticulture.

TABLE I.—*A list of native and imported food plants of the hickory tiger-moth (Halisidota caryae).*

Acer saccharinum L. Silver maple. (Beutenmüller 1890.)
Acer pseudoplatanus L. Sycamore maple. (Beutenmüller 1890.)
Acer rubrum L. Red maple. (Beutenmüller 1890.)
Acer negundo L. Boxelder. (Beutenmüller 1890.)
Acer saccharum Marsh. Sugar maple. (Beutenmüller 1890.)
Aesculus glabra. Welld. Buckeye. (Beutenmüller 1890.)
Alnus rugosa (Du Roi). Alder. (Beutenmüller 1890.)
Betula a. var. *papyrifera* Marsh. Paper birch. (Beutenmüller 1890.)
Betula populifolia Marsh. Gray birch. (Beutenmüller 1890.)
Carpinus caroliniana Wall. Hornbeam. (Beutenmüller 1890.)
Carya sp. Hickory. (Harris 1841.)
Carya alba (L.) White hickory. (Beutenmüller 1890.)
Carya glabra (Mill.). (Beutenmüller 1890.)
Castanea dentata (Marsh). Chestnut. (Beutenmüller 1890.)
Celtis occidentalis L. Hackberry. (Beutenmüller 1890.)
Crataegus sp. Thorn. (Soule 1891.)
Cydonia oblonga Mill. Quince.[1]

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[1] Confirmed by writer.

Fagus grandifolia Ehrh. Beech. (Beutenmüller 1890.)
Fraxinus sp. Ash. (Harris 1841.)
Hamamelis virginica L. Witch-hazel. (Beutenmüller 1890.)
Juglans cinerea L. Butternut.[1] (Fitch 1855.)
Juglans nigra L. Black walnut.[1] (Fitch 1855.)
Juglans regia L. English walnut.[1]
Juglans sieboldiana Maxim. Japanese walnut.[1]
Larix decidua Mill. Tamarack. (Fitch, according to Felt, 1905.)
Larix laricina (Du Roi). Larch. (Fitch, according to Felt, 1905.)
Ostrya virginiana (Mill.). Hop hornbeam.[1]
Prunus serotina Ehrh. Black cherry.[1] (Beutenmüller 1890.)
Prunus virginica L. Chokecherry. (Beutenmüller 1890.)
Prunus cerasus. Sour cherry. (Lintner 1891.)
Platanus occidentalis L. Sycamore. (Beutenmüller 1890.)
Platanus orientalis L. Sycamore. (Beutenmüller 1890.)
Pyrus communis L. Pear.[1] (Lintner 1891.)
Pyrus malus L. Apple.[1] (Beutenmüller 1890.)
Quercus alba L. White oak. (Beutenmüller 1890.)
Quercus palustris Muench. Pin oak. (Beutenmüller 1890.)
Quercus rubra L. Red oak. (Beutenmüller 1890.)
Rhus sp. Sumach. (Fitch 1855.)
Rosa sp.[1]
Rubus sp. Raspberry. (Eliot and Soule 1902.)
Tilia americana L. Basswood. Beutenmüller 1890.)
Tilia alba. White linden. (Beutenmüller 1890.)
Tilia europea. European linden. (Beutenmüller 1890.)
Salix sp. Willow. (Eliot and Soule 1902.)
Ulmus sp. Elm. (Harris 1841.)
Ulmus americana L. American elm. (Beutenmüller 1890.)
Ulmus campestris L. English elm. (Beutenmüller 1890.)
Ulmus fulva Michx. Slippery elm. (Fitch 1855.)

SEASONAL HISTORY.

EMERGENCE OF MOTHS.

There is one generation annually. The insect pupates in the fall, hibernates in the pupa stage, and the moths emerge in early summer. During the season of 1916 the earliest emergence from a lot of 36 cocoons was June 9 and the latest June 24, the majority emerging from June 12 to 15, inclusive. No adults were reared in either of the two previous seasons, but in 1914 larvæ were found in the field as early as June 18, indicating that moths must have emerged as early as June 1. In 1915 the larvæ appeared in the field about the same time as in 1916. The data relating to emergence of moths in 1916 are given in Table II.

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[1] Confirmed by writer.

TABLE II.—*Time of emergence of adults of the hickory tiger-moth at North East, Pa., 1916.*

Date of emergence.	Total number of moths.	Number of males.	Number of females.	Date of emergence.	Total number of moths.	Number of males.	Number of females.
June 9	1	1		June 16	1		1
10	1	1		19	1		1
12	4	3	1	22	1		1
13	8	7	1	24	1		1
14	4	3	1				
15	3	2	1	Total	25	17	8

LENGTH OF EGG STAGE.

The length of the egg stage, based on records from 4 egg masses deposited in 1916, was 15 to 16 days. Two masses of eggs deposited June 15 hatched July 1; one mass deposited the same day hatched July 2; the fourth mass, deposited June 16, hatched July 3.

DURATION OF LARVAL FEEDING PERIOD.

The duration of the larval feeding period varies greatly. Miss Soule (8) records rearing one colony from egg to cocoon in 47 days, which passed through only 7 instars. During the season of 1915 larvæ reared by the writer on Japanese walnut required from 62 to 85 days from egg to cocoon, averaging 74.73 days. (See Table III.)

TABLE III.—*Duration of the larval feeding period, North East, Pa., 1915.*

Number of individuals.	Duration of larval feeding period.	Number of individuals.	Duration of larval feeding period.	Number of individuals.	Duration of larval feeding period.
	Days.		*Days.*		*Days.*
1	62	1	72	2	79
1	64	2	74	2	80
1	66	1	75	1	82
1	68	2	76	1	85
1	70	1	77		
1	71	3	78	22	[1] 74.73

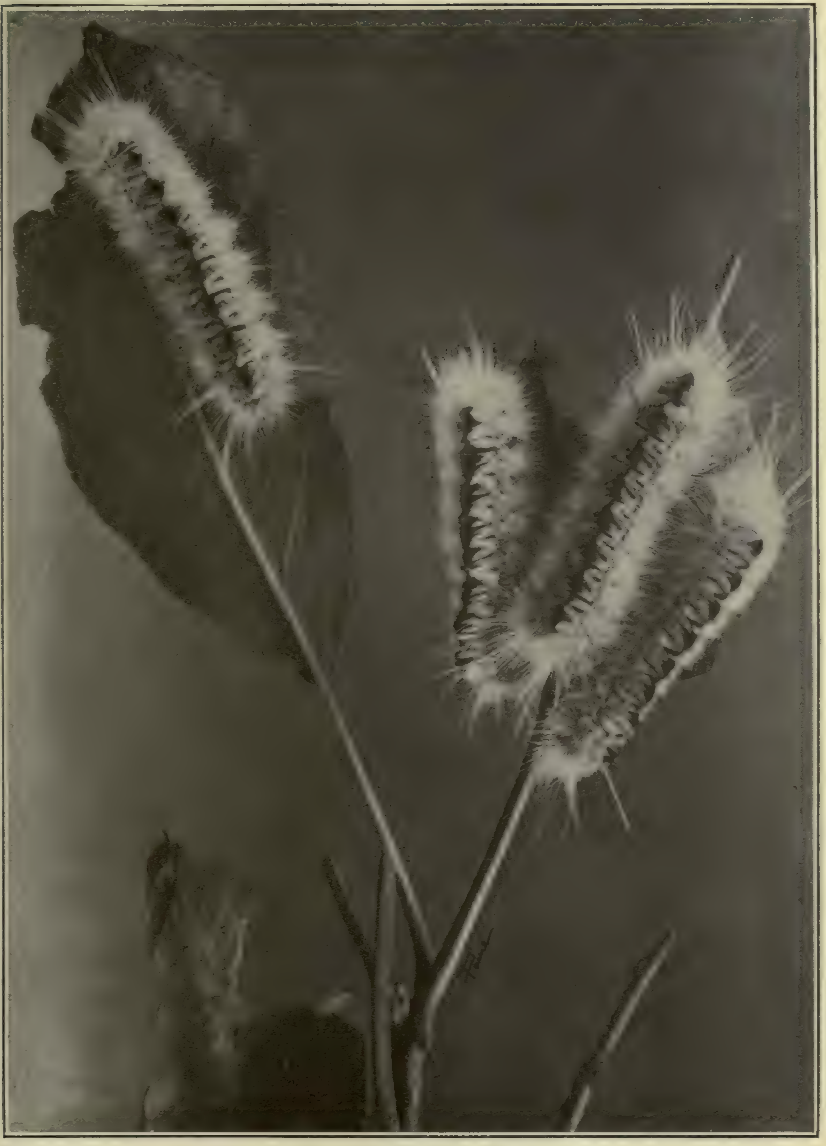
[1] Average.

During the season of 1916 larvæ reared on the same food plant required 80 to 100 days, averaging 89.04 days. (See Table IV.)

TABLE IV.—*Duration of the larval feeding period, North East, Pa., 1916.*

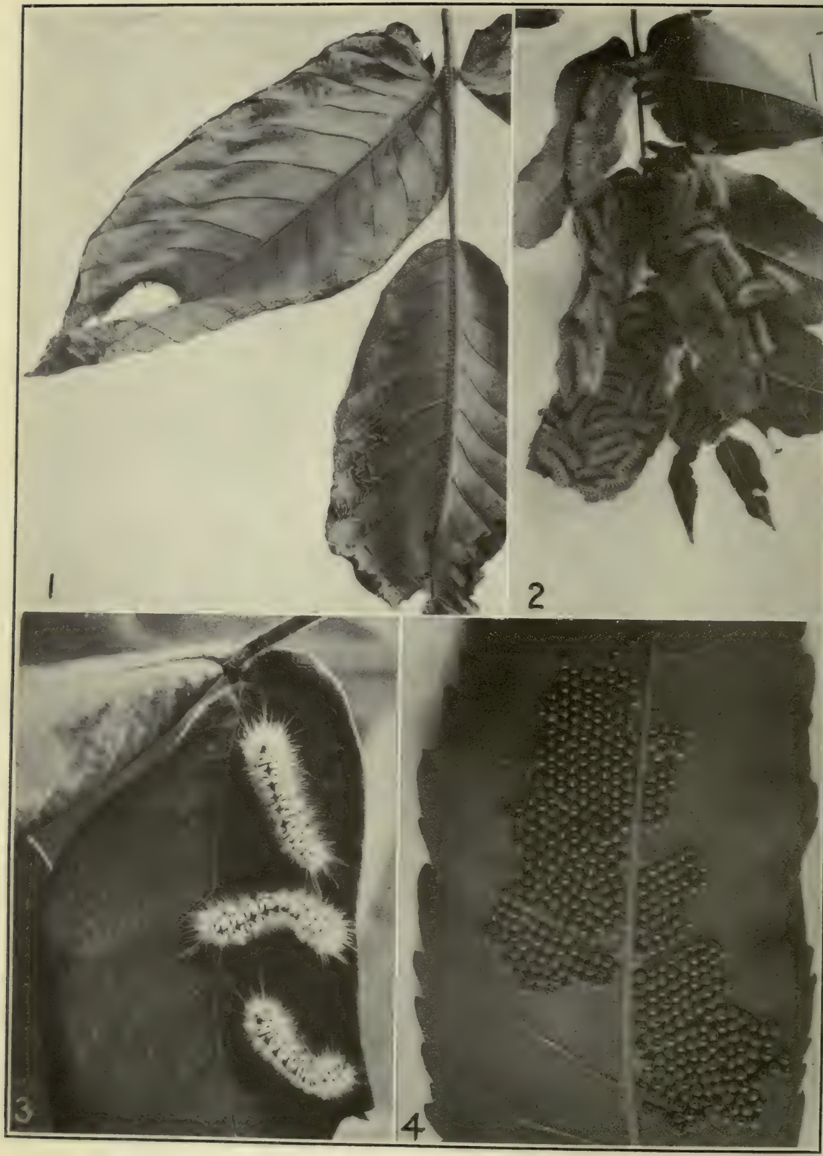
Number of larvæ.	Duration of larval feeding period.	Number of larvæ.	Duration of larval feeding period.	Number of larvæ.	Duration of larval feeding period.
	Days.		*Days.*		*Days.*
3	80	15	88	2	94
2	82	31	89	2	95
4	83	26	90	1	96
9	84	4	91	1	100
6	85	6	92		
21	86	8	93	145	[1] 89.04
4	87				

[1] Average.



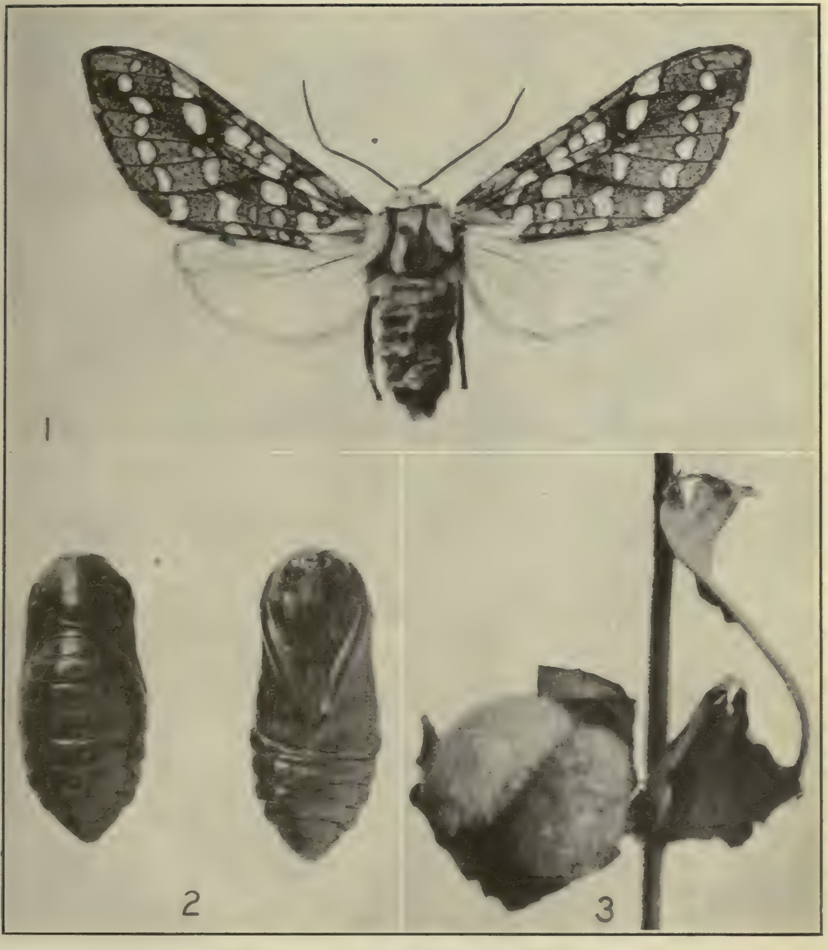
THE HICKORY TIGER-MOTH.

Larvæ on apple leaves, ninth instar. (Original.)



STAGES OF THE HICKORY TIGER-MOTH.

FIG. 1.—Larvæ, first instar. FIG. 2.—Fourth instar. FIG. 3.—Seventh instar. FIG. 4.—Eggs. (Original.)



THE HICKORY TIGER-MOTH AND STAGES.

FIG. 1.—Adult. FIG. 2.—Pupæ. FIG. 3.—Cocoons. (Original.)

The larvæ reared in 1915 passed through only 8 instars, but the majority of those reared in 1916 passed through 9 instars. This could not have affected greatly the time required for development, however, as the few larvæ which passed through only 8 stages in 1916 required an average of 88.71 days. In 1915 the larvæ were reared under natural conditions in bags on a tree, whereas in 1916 all lots but one were reared in battery jars. The one lot of 22 larvæ reared on the tree in 1916 required from 85 to 92 days from egg to cocoon, with an average of 87.18 days, very nearly the same as that of those reared in confinement.

No explanation is offered for the difference in time required for development of larvæ in the two seasons, but it should be stated that the season of 1915 was excessively rainy, whereas the 1916 season was excessively dry. It is probable that humidity affected the rate of development either directly or by its effect upon the food plant.

The duration of the larval feeding period varies somewhat when different food plants are used. The development of those reared on apple was similar to that on walnut, but a little slower, and the larvæ passed through only 8 stages. The shortest period required for development from egg to cocoon was 89 days and the longest was 96 days, with an average of 92.87 days.

Pear seemed a slightly more favorable food plant than apple. The development of the larvæ was more rapid, and although the majority passed through only 8 stages a few passed through 9 stages. Eighteen larvæ which passed through 8 stages required from 87 to 91 days, with an average of 88.77 days; 5 larvæ which passed through 9 stages required from 98 to 100 days, averaging 98.40 days.

The duration of the stages of larvæ reared on Japanese walnut during the season of 1916 was as follows:

First stage: Minimum 6 days, maximum 7 days, average 6.12 days; 232 larvæ reared.

Second stage: Minimum 4 days. maximum 7 days, average 4.78 days; 232 larvæ reared.

Third stage: Minimum 5 days, maximum 7 days, average 5.62 days; 232 larvæ reared.

Fourth stage: Minimum 6 days, maximum 7 days, average 6.02 days; 232 larvæ reared.

Fifth stage: Minimum 6 days, maximum 8 days, average 6.25 days; 232 larvæ reared.

Sixth stage: Minimum 6 days, maximum 13 days, average 8.52 days; 145 larvæ reared.

Seventh stage: Minimum 8 days, maximum 20 days, average 12.33 days; 145 larvæ reared.

Eighth stage (excluding larvæ that completed their feeding period in this stage): Minimum 13 days, maximum 25 days, average 18.03 days; 138 larvæ reared.

Eighth feeding stage (including only larvæ that spun cocoons at end of this instar): Minimum 19 days, maximum 29 days, average 23.29 days; 7 larvæ reared.

Ninth feeding stage (until spinning of cocoons): Minimum 13 days, maximum 26 days, average 20.95 days; 138 larvæ reared.

The period covered by the rearing records in 1915 began when the larvæ under observation hatched, on July 17, and continued until time of spinning cocoons, which extended from September 17 to October 10. In 1916 the earliest larvæ hatched June 30, and the first cocoon under observation was spun September 24 and the latest October 10.

DURATION OF PREPUPA PERIOD.

The larva period in the cocoon at North East, Pa., in 1916 averaged between 7 and 8 days. Of 19 larvæ which spun cocoons on September 24, 25, and 26, 10 pupated in 7 days and 9 in 8 days.

HABITS.

THE LARVA.

Larvæ from the same egg mass hatch almost simultaneously and upon hatching eat the greater part of the eggshells. They are gregarious in the early stages, and even in the later stages molt together. During the first four stages they feed gregariously, beginning to scatter in the latter part of the fourth. If during the first three stages a larva is separated from its fellows and is placed on a separate leaf or shoot, it will invariably find its way back to the others within a few hours. When one leaf or shoot is stripped the larvæ move in mass to another, often to another part of the tree.

After the fifth stage the larvæ scatter more or less and are solitary except about molting time. Often they migrate to trees quite a distance from the one on which the colony started. After the last molt the larvæ scatter widely.

The molting of the majority of larvæ from a given egg mass is almost simultaneous, and at this time the gregarious habit is most pronounced. Even after larvæ have scattered over a tree they come together to molt. A short time before molting a silken mat is spun upon which the larvæ rest for about a day before the early molts and sometimes for several days before later ones. This molting mat is spun upon a leaf or bunch of leaves, and sometimes before the later molts on the side of a branch or tree trunk. At each molting period there are often a few larvæ which fall behind and fail to molt with the rest. These invariably develop very slowly and usually do not mature.

Feeding injury is seldom conspicuous and usually unnoticed until the third or fourth instar is reached when the larvæ become very voracious. Larvæ in the first stage are surface feeders. Those on walnut and pear feed on the underside, eating nearly to the upper epidermis. Those on apple and quince feed on the surface. On these food plants the larvæ eat the leaf tissue as they go, while larvæ on cherry and oak leave patches of surface uneaten and also may feed on either upper or lower surface of the leaf. Larvæ in the second stage feeding on walnut and in the third stage on pomaceous fruits feed at the edge of the leaf, eating everything except the thicker leaf veins.

The cocoon is spun among leaves or in protected situations on the ground. If the infested trees are in the neighborhood of buildings cocoons may be found under boards, behind doors, or in similar situations.

THE PUPA.

The pupa hibernates on the ground. Moisture is probably necessary for successful hibernation, for from 36 cocoons wintered out of doors in a screen basket 25 moths emerged, whereas from 21 cocoons wintered in the insectary in a battery jar and protected from snow and rain, but exposed to the same temperature conditions, none emerged.

THE MOTH.

In emerging the moth usually breaks the pupal skin and then forces its way out of the end of the cocoon. If the cocoon is very loosely constructed the pupa may break out of it before eclosion, but this is not usual.

Copulation has been noted as early as the day of emergence and oviposition as early as 3 days thereafter. One moth continued ovipositing for 2 days, day and night, apparently without interruption, adding eggs to the same egg mass. Oviposition is performed deliberately. The moth's wings are folded back at rest at this time.

Moths oviposit readily in cages without being fed. They seem to prefer to oviposit on Japanese walnut leaves but will place eggs on cheesecloth or on the sides of the cage. The moths are very sluggish and can be handled easily in cages.

PARASITES.

This insect is remarkably free from parasitic enemies. None has been reared by the writer, and as far as he is aware only one species, *Pimpla pedalis* Cress (18), has been recorded.

ECONOMIC IMPORTANCE.

Injury by this insect is intensive and not extensive. It is due to the gregarious larvæ of the early stages which strip branches and sometimes small trees of their foliage. The injury to young trees in particular may be severe. After the gregarious habit is lost the larvæ scatter so widely that the injury done by them is inconspicuous.

Infestation by this insect so far as the writer has observed is not general even within an orchard. Several colonies of larvæ may be on one tree, but the writer has never seen a large tree completely stripped. Usually damage occurs in young orchards on which the codling-moth sprays have not been applied. The increasing importance of the cultivated walnut trees in the northeastern United States probably will cause this pest to become correspondingly more important.

CONTROL.

Spraying with arsenicals is the usual recommendation for the control of this pest. In orchards which have been thoroughly sprayed for the codling moth the writer has never noted an infestation. Nevertheless, the caterpillar soon becomes very hard to poison, and very large amounts are required to kill it in the later stages.

If control measures are not adopted until the larvæ are in evidence, they probably will not be applied until some of the larvæ are in the third or fourth instar. Spraying at this time is likely to produce discouraging results. Two trees infested with colonies of fourth-stage larvæ were sprayed with arsenate of lead July 31, 1915; on one the poison was applied at the rate of 3 pounds (paste) to 50 gallons and on the other 5 pounds (paste) to 50 gallons. None of the larvæ died until two days later on the tree sprayed with the larger amount of poison, and not until three days later on the tree sprayed with the smaller amount. On the tree sprayed with the smaller amount about 10 per cent of the larvæ survived. It was evident that unless they fed on poisoned leaves continuously for some time they were not affected at all. Unless the larvæ are confined on a sprayed tree they are very likely to migrate to another before eating enough to kill them.

In the gregarious stages colonies of these larvæ are easily collected and destroyed. When the infestation is scattered throughout an orchard this method is much the cheapest that can be employed and is entirely effective.

On young orchards which would not receive the spring spray applications for the codling moth, an application about the last of June of arsenate of lead (paste), 3 pounds to 50 gallons of liquid, would be of value in preventing injury by this pest.

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Insects Injurious in Cranberry Culture. (Farmers' Bulletin 178.) 1903. Price, 5 cents.
Spraying for Apple Diseases and Codling Moth in the Ozarks. (Farmers' Bulletin 283.) 1907. Price, 5 cents.
Danger of General Spread of Gipsy and Brown-tail Moths Through Imported Nursery Stock. (Farmers' Bulletin 453.) Price, 5 cents.
More Important Insect and Fungous Enemies of Fruit and Foliage of Apple. (Farmers' Bulletin 492.) Price, 5 cents.

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SPRAYING FOR THE CONTROL OF INSECTS AND MITES ATTACKING CITRUS TREES IN FLORIDA

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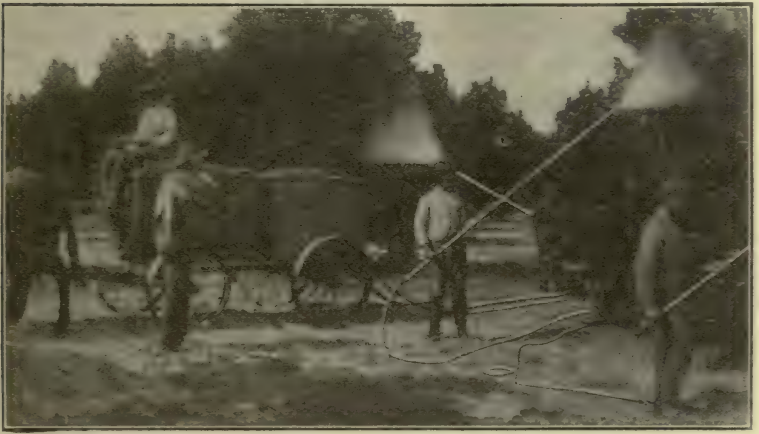

FARMERS' BULLETIN 933

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. Issued March, 1918

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UNDER FLORIDA CONDITIONS spraying is the most effective method for the control of citrus pests. In the past there have been many failures, and much money has been expended without adequate returns to the grower in better fruit and increased yields. These failures have been due to various causes, such as improper equipment, ineffective insecticides, and a lack of a proper spraying schedule.

This bulletin gives information regarding the best equipment for Florida conditions, and directions for preparing effective homemade insecticides. There is also given a spraying schedule that has proved satisfactory after several years of practical experience and such other information as will enable the grower to control citrus pests in a satisfactory manner.

Spraying improves the grades of the fruit and increases the yield of the trees out of all proportion to its cost, if the work is done properly.

SPRAYING FOR THE CONTROL OF INSECTS AND MITES ATTACKING CITRUS TREES IN FLORIDA.

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SUCCESS OF INSECTICIDES AND SPRAY SCHEDULES.

RELIABLE INSECTICIDES for the control of insects and mites attacking citrus trees in Florida have been developed and tested on a large scale. These insecticides, and the spray schedule now recommended for citrus groves, have been used with success for four years.

The best argument in favor of the sprays and spraying scheme discussed in this bulletin is to be found in the difficulty the writer has had in securing the same grove for demonstration spraying two or three years in succession. Once the owner of a grove has seen the benefits resulting from careful and well-timed spraying he refuses to accept the losses that he knows will come to him through the setting aside of blocks of trees to be left unsprayed for comparison with those sprayed.

CITRUS INSECTS AND MITES OF IMPORTANCE.

Of the total damage caused to citrus trees by insects and mites in Florida, more than 95 per cent may be attributed to six species. These are, in the order of their destructiveness, the citrus white fly (figs. 1, 2, 19),[1] the purple scale (fig. 4),[2] the rust mite (fig. 6),[3] the Florida red scale (figs. 4, 5),[4] the cloudy-winged white fly (fig. 3),[5] and the red spider or six-spotted mite.[6] There are several other pests of minor importance, such as the woolly white fly,[7] the purple mite,[8] and the chaff scale.[9] The citrus white fly, the most injurious of pests, now infests nearly all the groves of Florida, and the purple scale is found in greater or less numbers on every citrus tree.

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[1] *Dialeurodes citri* (Ashmead).

[2] *Lepidosaphes beckii* (Newman).

[3] *Phyllocoptes oleivorus* (Ashmead).

[4] *Chrysomphalus aonidum* (Linnaeus).

[5] *Dialeurodes citrifolii* (Morgan).

[6] *Tetranychus sexmaculatus* Riley.

[7] *Aleurothrixus howardi* (Quaintance).

[8] *Tetranychus citri* McGregor.

[9] *Parlatoria pergandii* Comstock.

LOSSES RESULTING FROM INSECT ATTACK.

The presence of pests on citrus fruit usually causes blemishes that place such fruit in a lower grade. It is generally considered that fruit which has been attacked by the rust mite is also one size, or 12½ per cent, smaller than it would otherwise be. Fruit without blemishes caused by pests probably will reach the market with less decay.

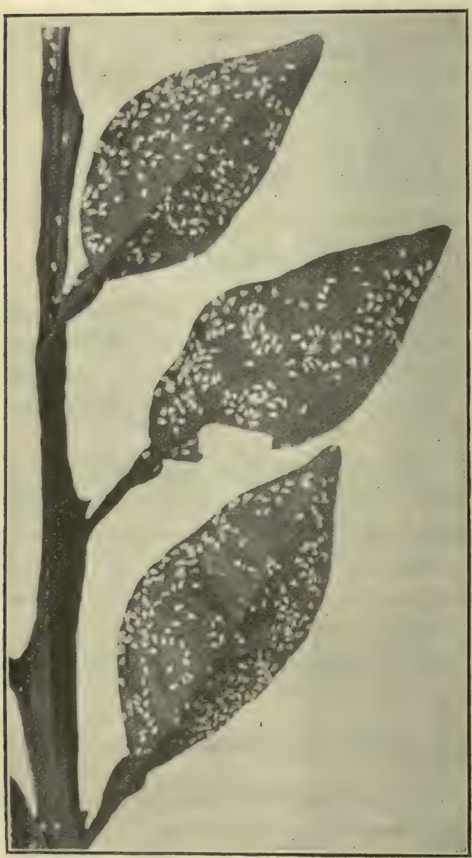

FIG. 1.—Adults of the citrus white fly crowding the under surface of new orange leaves. Adults appear slightly less than normal size. (Morrill and Back.)

The better grades of fruit are more marketable. High-grade fruit finds an early and ready market. Fruit badly attacked by insects and mites is usually sold late in the season, after sustaining large losses from dropping and incurring the liability of damage from frosts.

The work of the pests devitalizes the trees. Much of the bearing wood on the inside of the tree is killed, thus reducing the yield. It requires much additional fertilizer to produce a crop of fruit when pests are present.

METHODS OF CONTROLLING CITRUS PESTS IN FLORIDA.

Florida growers have attempted to control citrus pests by three methods: (1) Fumigation, (2) spraying, and (3) encouragement of beneficial fungi.

FUMIGATION AND SPRAYING.

Of the two artificial methods of control, spraying and fumigation, spraying is superior under Florida conditions at present. Fumigation—excellent as it is under weather conditions such as exist in California—is not promising in Florida, where the dormant season for citrus trees is too short to permit of the advantageous use on a large scale of fumigating outfits. There are also other objections to the general adoption of fumigation for the average grove in Florida. On some groves, however, fumigation[1] could be used successfully.

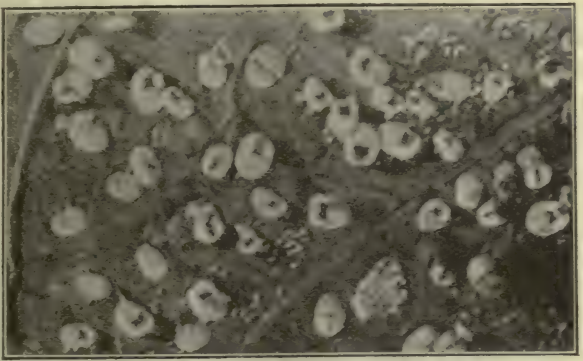

FIG. 2.—Pupæ and pupa cases of the citrus white fly. The pupa cases do not collapse after the adult emerges, like those of the cloudy-winged white fly, but remain rigid. (Morrill and Back.)

FUNGI.

There are a number of beneficial fungi that kill insects in Florida. These do an immense amount of good and should be present in every grove in the State. The most valuable of those killing citrus insects are the red-headed[2] and gray-headed[3] fungi that kill the purple scale, and the red (fig. 7),[4] yellow,[5] brown (fig. 8),[6] and white-fringe[7] fungi that kill the white flies. Under the most favorable climatic conditions these fungi keep the insects well in check. These favorable conditions usually do not obtain, and both scale insects and white flies become abundant and cause much damage, often before a grower realizes the true situation. These fungi are active about five months during the rainy season in summer, leaving many of the injurious insects to multiply unchecked

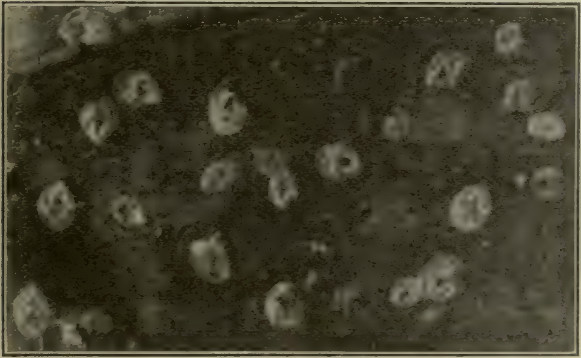

FIG. 3.—Pupa cases of the cloudy-winged white fly. They are very filmy, collapse after the adult emerges, and fall easily from the leaf. (Morrill and Back.)

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[1] Morrill, A. W. "Fumigation for the citrus white fly, as adapted to Florida conditions." U. S. Dept. Agr., Bur. Ent. Bul. 76. For sale by Superintendent of Documents, Washington, D. C., for 15 cents.

[2] *Sphaerostilbe coccophila* Tul.

[3] *Ophionectria coccicola* E. & E.

[4] *Aschersonia aleyrodis* Webber.

[5] *Aschersonia flavo-citrina* P. Henn.

[6] *Aegerita webberi* Fawcett.

[7] *Microcera* sp.

during the remainder of the year. The fungi kill the insects only after the tree has given up its vitality to furnish nourishment for the insects' development. As a rule, when fungi are depended upon as the only method to free trees from insect attack, the trees are left in a weakened condition, often with much dead bearing wood and sparse foliage, before the fungi succeed in temporarily reducing the insects to a point where little damage follows.

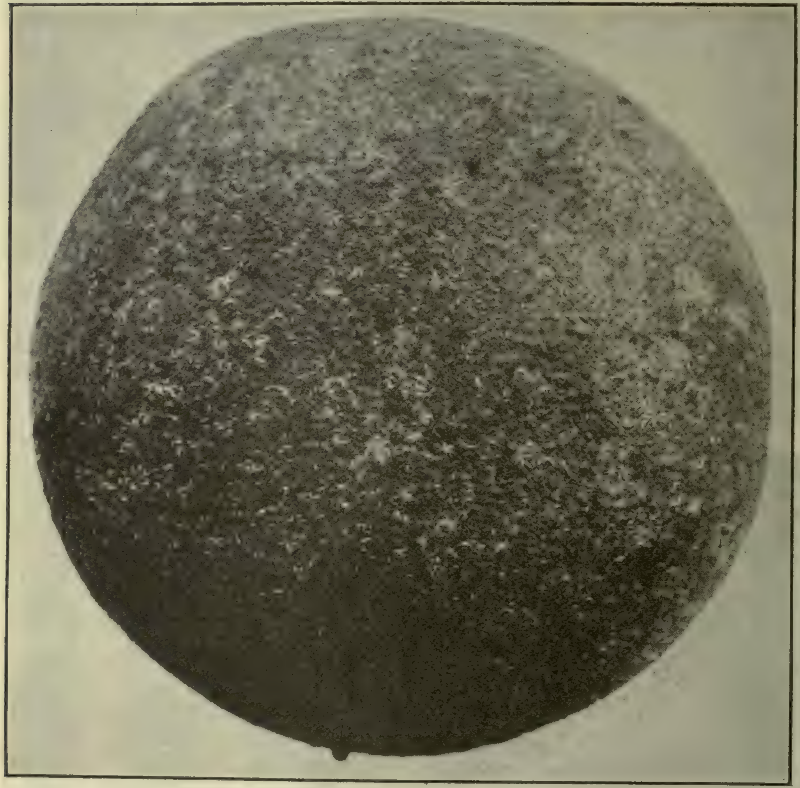

FIG. 4.—A grapefruit heavily infested with both the Florida red and the purple scales in all stages of development. Note that the scales form a scurf over the rind.

SPRAYING COMING INTO GREATER FAVOR.

Enthusiastic supporters of control by natural agencies contend that it is more profitable to grow lower grades of fruit without treatment than the better grades with treatment. Yet a system of spraying for improving grove conditions has been gradually adopted by men who, only a few years before the Bureau of Entomology began its work, depended upon fungi as the best all-round method of control. This change from dependence upon fungi to spraying with insecticides has come partly through the realization that parasitic fungi, excellent as they are, are not a complete method of insect control, but should be supplemented by spraying with insecticides. The growing use of spray mixtures and the spraying schedule advocated in this bulletin has also been an influential factor in bringing about this change. Spraying as a method of control has been followed successfully in Florida by many who are acknowledged to be successful growers.

REASONS FOR BAD RESULTS IN THE PAST.

Spraying, however, taken throughout the citrus area, has not yielded satisfactory results. Growers have not obtained satisfactory results from spraying and have become discouraged for two main reasons: (1) Lack of reasonable thoroughness on the part of laborers and (2) lack of a proper appreciation of the requirements for spraying on the part of the grove owner. (See fig. 9.)

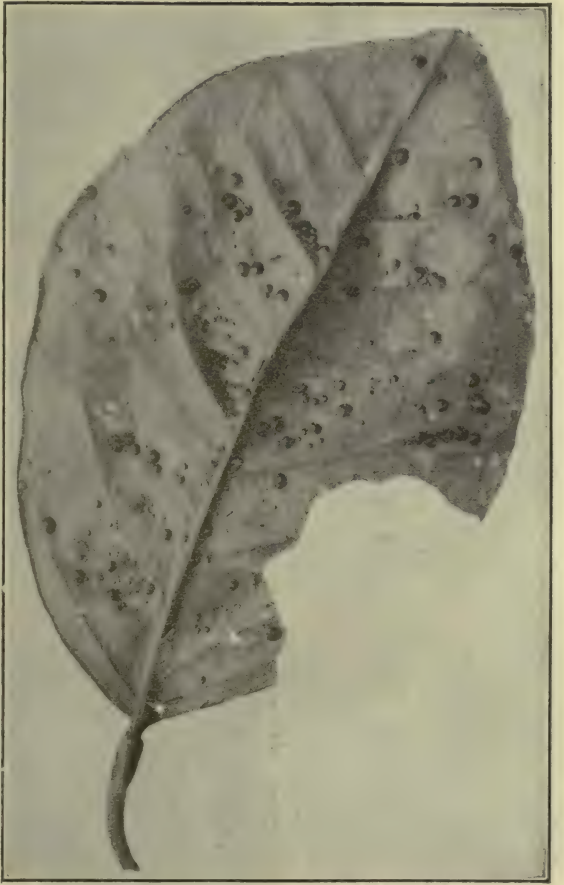

FIG. 5.—The Florida red scale, showing the adult females and young stages. The lower portion of the leaf has been eaten by a grasshopper.

Because success did not follow a single haphazard application of an ineffective insecticide, spraying has been pronounced a failure by many. The writer has examined leaves from sprayed groves and found not more than 10 per cent of the insects killed. He has known personally of instances in which grove owners have purchased reliable and expensive power sprayers only to turn over the mixing of the insecticide and the spraying of the trees to uninstructed labor. Many fine groves have been sprayed by men who did not hit 40 per cent of the insects with the spray. One crew operating a power outfit did not hit the lower surface of more than 1 leaf in 1,000. Spraying can not succeed under such conditions.

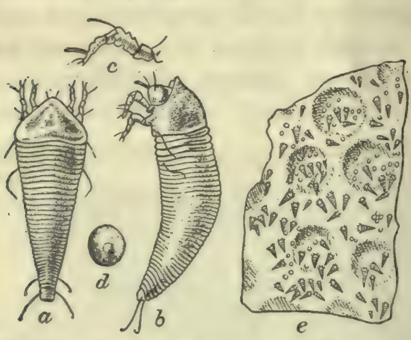

FIG. 6.—The rust or silver mite: *a* and *b*, Dorsal and lateral views of adult mite; *c*, leg of same; *d*, egg; *e*, lemon rind showing pits normal to surface and mites and eggs. All greatly enlarged. (*a* to *d*, Copied from Hubbard; *e*, Marlatt.)

EQUIPMENT FOR SPRAYING.

Much dissatisfaction in spraying for the control of pests on citrus trees arises from the use of inefficient equipment. The equipment for spraying should be adapted to the particular needs of the grower and also to the size of the trees and the nature of the grove to be sprayed.

PUMPS.

Barrel pump.—A barrel pump (fig. 10), which will supply one lead of hose, will serve every purpose if the trees are low and only a small amount of spraying is required, and will save investment in a large machine until such time as the work necessitates one. For three years or longer after planting this pump will answer the purpose very satisfactorily. In fact, one of the most successful grove owners, who sprays, has used a barrel pump for three years in his grove of 800 trees about 10 feet in height. A barrel pump, indeed, is a necessity in any grove where insects are controlled by spraying. Many times it is necessary to spray one tree only, and this can be done easily with a barrel pump, thus eliminating the necessity of using a large machine.

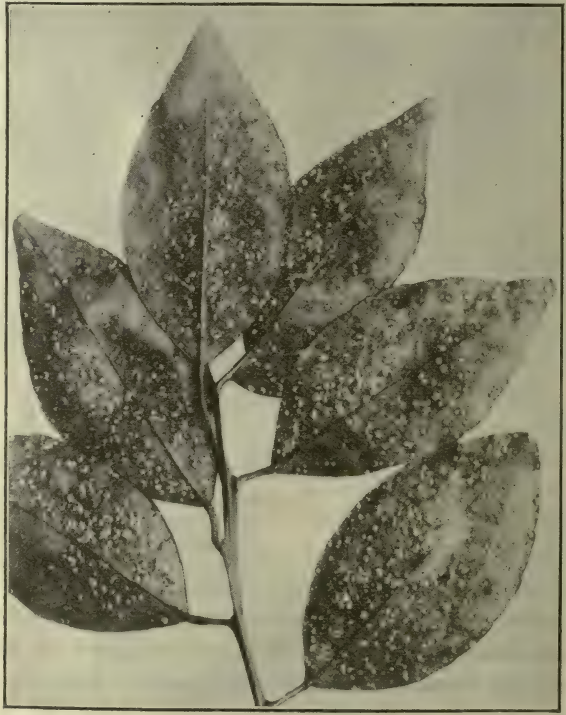

FIG. 7.—Red fungus attacking the citrus white fly. (Morrill and Back.)

in groves where palmetto and other trees have not been removed, and in groves so thickly planted that it is difficult to use a power sprayer. A barrel pump can be used also for making emulsions and for whitewashing.

For extensive operations, however, experience indicates that either a large lever pump or a gasoline power outfit should be used.

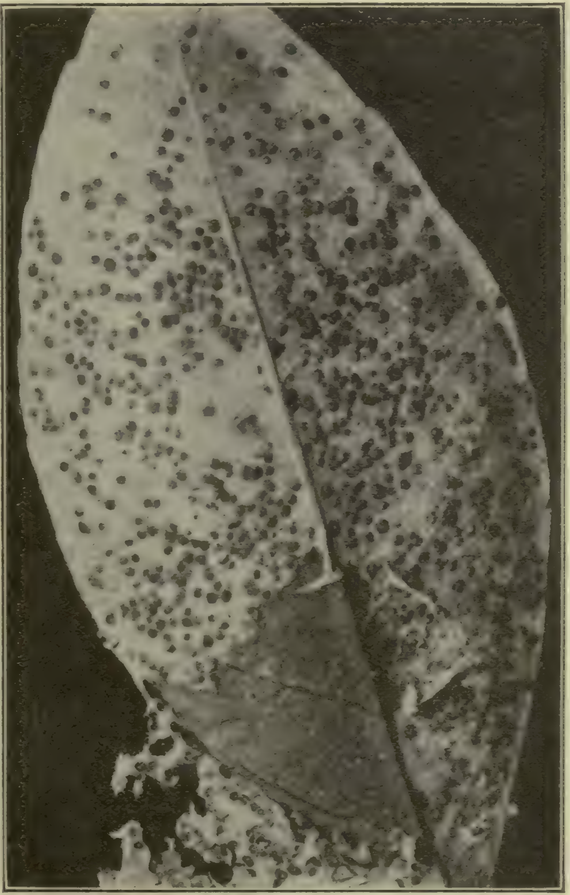

FIG. 8.—The brown fungus attacking the citrus white fly. The mycelium of the fungus has been turned back from the lower left portion of the leaf. (Morrill and Back.)

Lever pump.—The large double-acting hand pump (fig. 11) can be used for spraying even the largest trees and may be recommended for groves as large as 10 acres. This type of pump, like the barrel pump, seldom needs repairs and will supply two nozzles very satisfactorily. These pumps can be purchased in connection with a tank or separately. If purchased separately, a barrel is used to hold the spray material. The chief difficulty with both the barrel pump and the lever pump is the fact that it costs at least the wages of one man to furnish the power. This usually amounts to about 6 to 10 times as much as the cost for gasoline to run a power outfit. Another disadvantage in using any type of hand-power pump is the irregularity of the pressure and the lack of stimulus to the men that is furnished by a power-driven machine.

Gasoline power outfit.—For any extended work in spraying a power outfit (figs. 12, 13) should be used. Owing to the nature of the soil in Florida, spraying machines should be made as light in weight as possible. It is very doubtful if any machine is practical under the average grove conditions in Florida that weighs more than 1,800 pounds. To be of the greatest value a machine should weigh not more than 1,400 to 1,600 pounds. It is also desirable in many instances to have a cross reach for the truck which will permit it to be turned in a very small circle. The tires should be 6 inches in width and the diameter of the wheels should be as great as is practicable. In many instances, however, where the branches of the trees are near the ground, it is desirable to have the machine as low as possible to prevent pulling off fruit and the leaves. Some machines are built unnecessarily high and when used in such a grove cause much damage.

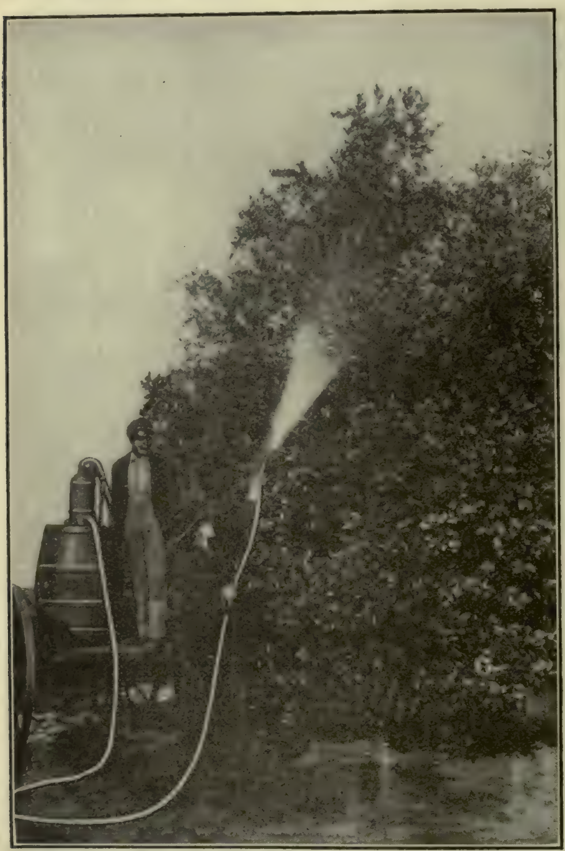
FIG. 9.—It is impossible to get good results without extension rods and this type of spraying is useless. The grower failing to get results condemns all spraying as useless when the fault lies in the lack of the proper equipment.

Since the wheels with which the spraying machines are fitted are extremely heavy, often comprising half of the weight of the empty machine, it is extremely desirable that lighter wheels be constructed for this special purpose. A machine for Florida conditions should be fitted with a tank located in front of the engine and pump (*not* as in fig. 14). This gives the operator an opportunity to attend the engine from the rear of the outfit without interfering with the team, and also eliminates the danger which usually follows when an engine is placed immediately in the rear of a pair of mules. The tank should contain an opening large enough to permit a man to go inside to clean it out. The opening should be fitted with a removable fine-mesh wire strainer. The tank and the cab over the engine and pump should be flush with each other (see fig. 13), in order to prevent the catching of branches, carrying off of fruit, and other injury to the trees.

The engine should be not less than 1½ horsepower. It is the consensus of opinion that a light engine of 2½ or 3½ horsepower is preferable to one of less power. The engine by all means should be fitted with a good governor. The pump should be fitted with a regulator which is accurate, and will take care of the capacity of the pump whether the nozzles are turned on or off. The pressure should not vary if the nozzles are cut off. Both the engine and the pump should be protected from sand by means of canvas curtains on the sides and rear. The wheels raise considerable sand to the height of the engine and pump and the wind may then blow it into the machinery. The writer has known of instances in which machinery unprotected from the sand has been ruined in a single week.

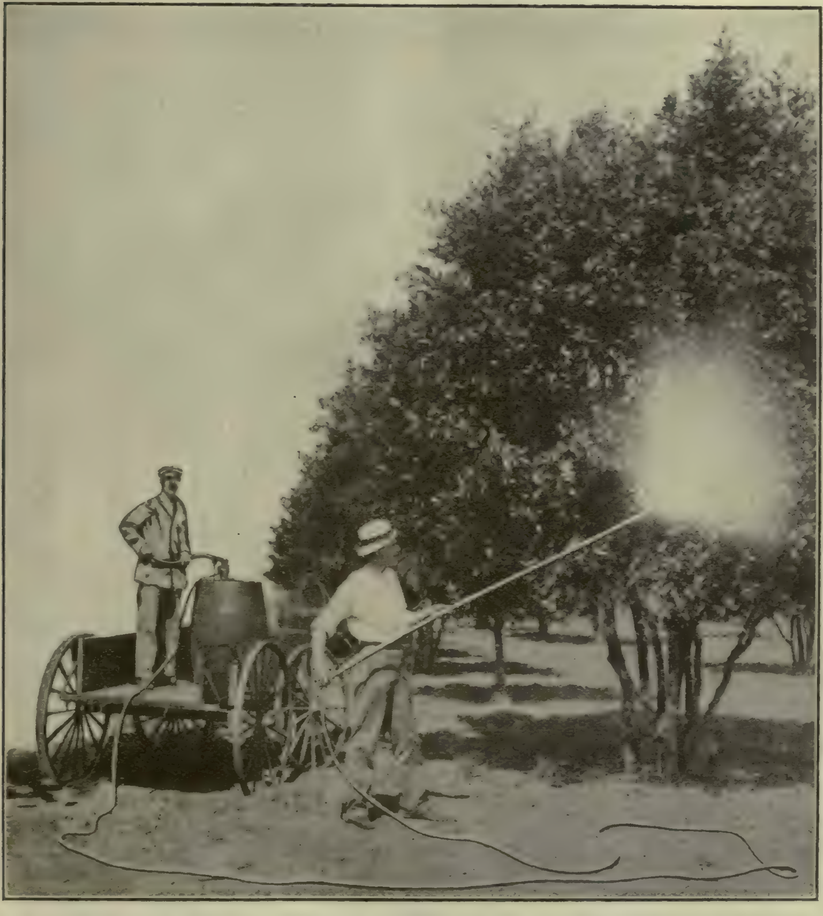

FIG. 10.—A barrel pump is satisfactory for small operations. The spray is directed upwards to hit the white fly infesting the lower surfaces of the leaves.

Unsatisfactory types of apparatus.—A pump run by means of gearing attached to the wheels (fig. 15) is not suitable for spraying citrus trees. It often requires as much as 15 gallons to spray a tree, and to apply this amount it would be necessary to spray a part of the tree and then drive the machine a considerable distance to get enough pressure in the air tank to continue spraying. This involves too great a waste of time and labor. No citrus grower should purchase such a machine for spraying citrus trees. It is also useless to attempt any spraying other than a few small trees with a bucket, small compressed air, or knapsack pump.

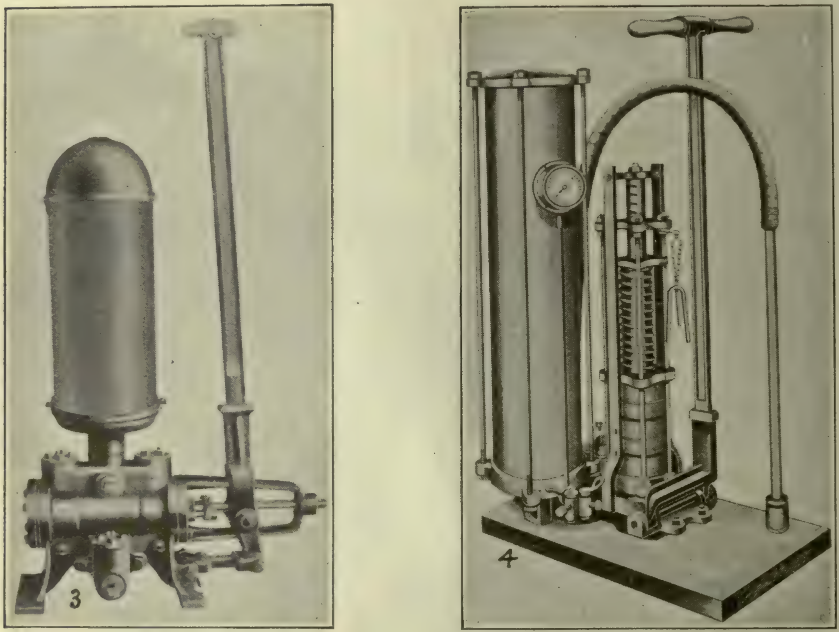

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FIG. 11.—These hand-power tank outfits are satisfactory for many groves in Florida. They are durable and do not easily get out of repair. They will supply two leads of hose, and may also be used in making emulsions. (Quaintance.)

HOSE.

The same kind of hose should be used for the barrel pump, the larger lever pump, and the power outfit. This hose should be not less than 7-ply if it is known as "wrapped." There is also a hose which is known as "double continuous net weave," which has given satisfactory results. This type is much lighter, and is therefore much easier to handle in a grove than the heavier type. So far, however, there are no indications as to whether the wrapped or the woven hose is superior. It is useless to attempt to spray with ordi-

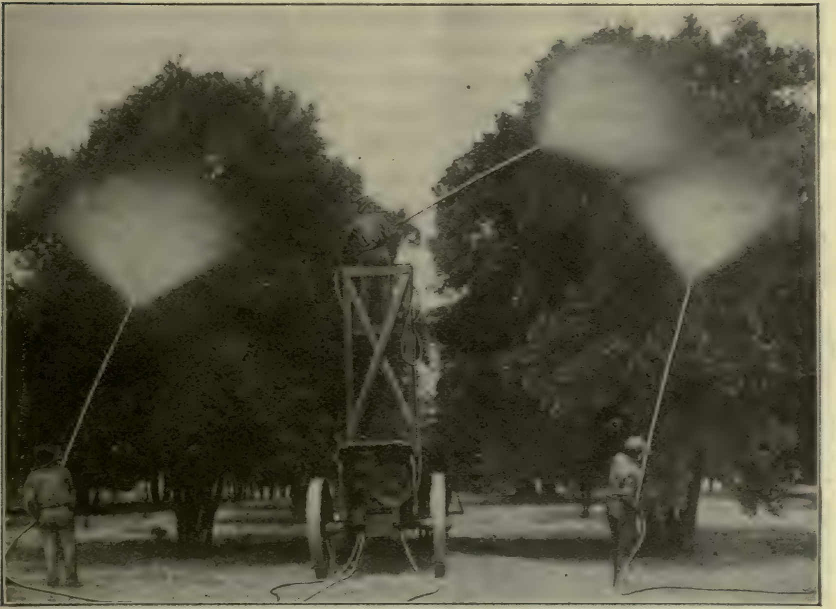

FIG. 12.—A power spraying outfit of the approved type with the engine in the rear where it can be attended without loss of time. Note the tower which enables the sprayer to reach the topmost branches of the trees.

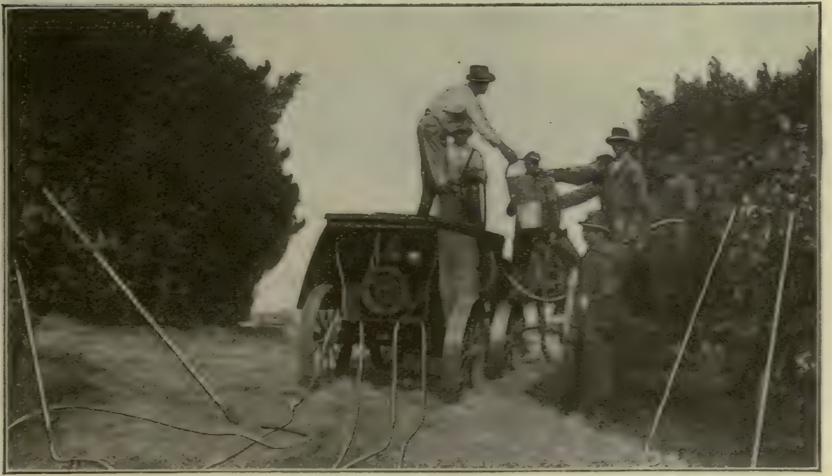

FIG. 13.—Water supply wagon to the right of the spraying machine. Such a wagon, used to haul water to the machine in the grove, nearly doubles the number of the trees that can be sprayed without much additional cost. Note that the cover over the engine is flush with the spray tank.

nary garden hose, even when using a barrel pump. The writer has broken garden hose in the space of one hour. Hose should be smooth on the outside instead of corrugated, since smooth hose can be repaired by wrapping with adhesive tape. Experience indicates that it is much better to have hose of one-half inch diameter than a smaller or a larger size.

For convenience in operation the leads of hose should be from 40 to 50 feet long. Hose of this length permits the operator to reach the farthest side of the largest trees in groves where they are planted at the average distance. Since the hose wears out first at the point of attachment to the machine or rod, this length permits the hose to be cut off and reattached without making it too short. With a long hose both the mules and the machine may be kept out of range of the spray.

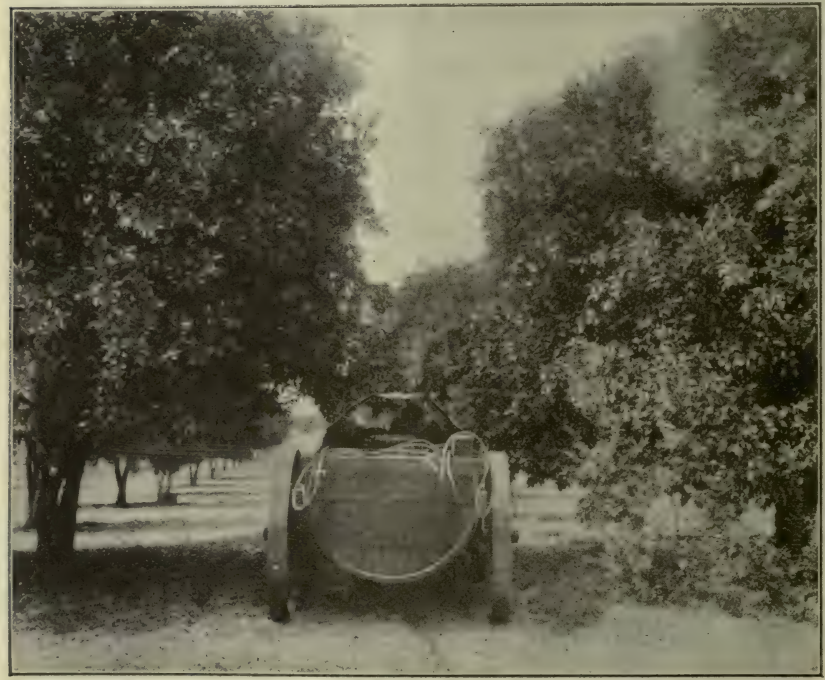

FIG. 14.—A power spraying machine of the underslung type, with the engine and pump forward, the tank in the rear.

RODS.

In spraying, an extension rod ranging from 8 to 12 feet in length should be supplied with each line of hose. The length will depend upon the height of the trees. This rod may be a regular bamboo rod or a small gas pipe. The former is more suitable for this work because it is lighter and more easily handled after becoming wet, and is not easily bent, hence the operator always knows just how to turn the rod to direct the spray upward. The bamboo rods, however, will not stand such rough usage as those made of gas pipe, and for this reason many growers have stopped using these light rods. An old piece of rubber hose may be slipped over the end which is attached to the hose, so that the operator may handle the rod with greater facility. Rods of gas piping should be kept straight and they should never exceed 10 feet in length. Owing to the more thorough work that can be done with the light bamboo rods, and the greater ease with which they may be handled, they should be used whenever practicable. With care they often last for years.

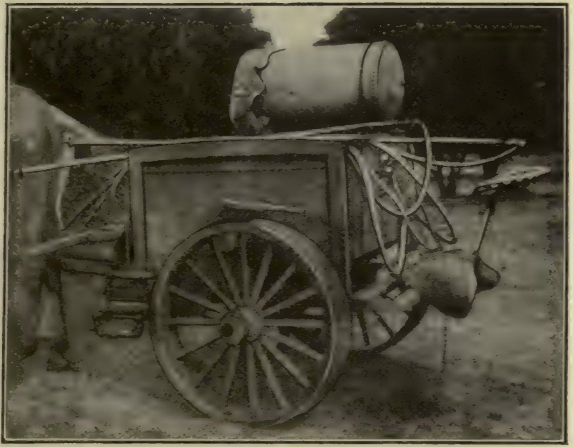

FIG. 15.—The geared spraying machine above is not suitable for spraying Florida citrus trees.

CUT-OFFS.

There should be a cut-off between each line of hose and the machine, so that if only one line of hose is required, or if an accident temporarily incapacitates one lead, the other lead or leads can be used. There should be an additional cut-off between each extension rod and the hose, so that the operator can prevent any undue waste of spray material, either in going from row to row or from tree to tree. A cut-off placed in this position will enable the operator to clean out any impediment in the nozzle without going back to the machine to cut off the liquid. A cut-off should always be kept in good repair, for if it does not cut off the spray *completely*, it is useless, and should be discarded or repaired immediately.

NOZZLES.

In spraying citrus trees the object is to obtain as wide a field as practicable so that the greatest amount of leaf surface can be sprayed in the shortest time. Penetration is not so important in spraying for the pests on citrus. An angle nozzle, from which the spray emerges in the form of a cone, at an angle of from 45° to 60°, is the best to obtain this result. It is also much better if two of these nozzles are placed on a Y so that the cones of spray intersect at from 8 inches to 12 inches from the nozzle. When so arranged the hollows of the cones are broken and it is much easier to attain a perfect wetting of all the foliage. The object in spraying a citrus tree should be the complete wetting of both the upper and lower surfaces of the leaves in the shortest possible time. The writer has found after many years' experience that much time is wasted in using nozzles of small capacity. It requires at least twice as long to spray a tree using a nozzle with a very tiny hole in the disk as it does using one of proper capacity. It is advisable to use a disk with an opening not less than one-twentieth of an inch in diameter and not greater perhaps than one-sixteenth of an inch.

SPRAYING ACCESSORIES.

Every outfit, whether it be a barrel pump, a large lever pump, or a power outfit, should be fitted with a wrench, pliers, hammer, and such other tools as are necessary. It will also save much trouble and annoyance if the materials which are placed in the tank are first strained through *double thicknesses of cheesecloth.* This will cost only a few cents and, according to the experience of the writer, may save several dollars a day in time. In case a small leak appears in the hose it can be dried carefully with a cloth and repaired with adhesive or "tire" tape; this has been known to double the durability of a hose. Copper wire or other wire should be available in order to repair hose connections in case they should separate. Patent hose clamps are now to be had, and if used these will eliminate much of the trouble usually arising from the separation of connections. Each outfit should be provided with proper measures and buckets to enable the operator accurately to calculate the amount of the insecticide used, besides buckets for filling the tank.

INSECTICIDES.

The pests of citrus trees considered in this bulletin may be divided into two groups with relation to the insecticides involved. (1) Those controlled by the soap-and-oil sprays, such as the white flies and scale insects; and (2) those controlled by the sulphur sprays, such as the rust mites and red spiders.

INSECTICIDES FOR WHITE FLIES AND SCALE INSECTS.

Experiments covering a 10-year period have shown that the best insecticides for controlling white flies and scale insects are those having a base of cheap lubricating oil or what may be called "paraffin oil." These oils are made into emulsions according to the formulas following.

Fish-oil soap at the rate of from 5 to 8 pounds to 50 gallons of water in May, or from 12 to 16 pounds to 50 gallons of water during the winter season, is an effective spray that has been used for many years without injury to the foliage or fruit.

While both the fish-oil soap and the oil emulsions are effective in killing the white flies and scale insects, experience indicates that the latter are far superior to the former under Florida conditions. This superiority is due to the physical properties of the oils. The high boiling point and great viscosity possessed by these oils make them operative over a longer period of time after application, and, too, they are only slowly affected by average temperatures and showers. Foliage sprayed with miscible oils remains slightly oily in appearance and to the touch for several weeks after spraying. Fish-oil soap leaves no such evidence that the trees have been sprayed. The oil spray is much less affected by showers than is the fish-oil-soap spray. Summer showers falling after the oil spray has once had an opportunity to dry on the foliage have little effect in lessening the efficiency of the spray. Such showers, however, have a very evident effect upon the number of insects killed by the soap spray. The effectiveness of the weaker strengths of fish-oil soap is much more reduced by showers than is the effectiveness of the weaker strengths of oil sprays.

In experimental work on a large scale for the control of the citrus white fly the miscible-oil sprays have given better results than have the soap sprays. This greater efficiency seems to be due, not to a higher percentage of larvæ and pupæ killed when the spray is applied, but to the effect that oil sprays exert upon unhatched eggs or upon the young larvæ hatching from them within 10 to 14 days after spraying. The oil forms a film over the eggs which prevents a large percentage from hatching, and the young larvæ from those which do hatch are killed either in the act of emerging from the shell or in crawling over the oil-coated leaf. Those who are in touch with the white-fly problem appreciate the fact that no matter how efficacious an insecticide may be, in killing larvæ and pupæ on the leaves at the time the spray is applied, if it does not either kill these unhatched eggs or remain operative long enough to kill the larvæ that subsequently hatch, much of the benefit of spraying is counterbalanced by reinfestation.

There are two ways of making miscible-oil emulsions: (1) Without heat; (2) with heat. The first is called the "cold-stirred emulsion"; the second, the "boiled" emulsion. Both kinds of emulsion are efficient, reliable, and easily made.

COLD-STIRRED EMULSION.

Formula.

Fish-oil soap:		
By weight	pounds	8
By measure	gallon	1
Paraffin oil, 24° or 28° Baumé	gallons	2
Water	gallon	1

Directions for preparation.—In preparing the stock mixture, the soap should be put into a receptacle of about five gallons' capacity and the oil added while the mixture is being vigorously stirred. It is important that the oil be added in small quantities at first, and that the stirring be sufficient to keep the oil and soap in the form of an emulsion after each addition of oil. Thus, at first about a pint of oil should be added to the soap and the mixture stirred until no free oil appears. As the amount of oil is increased it should always be stirred or mixed thoroughly before the next addition is made. After the required amount of oil has been added and after free oil has ceased to appear on top of the soap, the water is slowly poured in, about 1 quart at a time. As previously stated, the only apparatus required to make this formula in a small way is an ordinary galvanized iron pail and a paddle.

The foregoing formula may be modified under certain conditions, as the quantity of soap will depend largely upon the time consumed in adding the oil and the amount of stirring; the amount of soap being lessened if the stirring be uniform and ample time be taken in the careful preparation.

If it be desired to make this formula on a large scale, a 300-gallon cylindrical tank may be fitted with paddles, which are attached to a shaft in a vertical position, occupying the center of the tank. The shaft is fitted with a beveled gear on the upper end. A horizontal shaft is then connected with the vertical shaft by means of another beveled gear, while the other end has a pulley to connect with the engine. A series of brakes should be fitted to the sides of the tank to prevent the entire mass from turning around with the paddles. An entire barrel of fish-oil soap may be placed in this tank and the stirring begun at once. Two barrels of oil may then be run into the soap through an inch or 1½-inch hole in the end of the barrel, or the oil may be run out of the bung-hole. After the oil has been added, either one-half or two-thirds of one barrel of water can be added to complete the preparation of the stock solution. In the final spray this should be so diluted as to contain about 1 per cent of oil by adding 1 gallon of the stock solution to 50 gallons of water.

It is also highly practicable to fit up a 50-gallon barrel in the same way as described above for the 300-gallon tank. By attaching a crank to the horizontal shaft the mixer can be run by hand instead of by an engine. Such a mixer, designed and used by Mr. J. A. Stevens, De Land, Fla., has been found practicable. The writer has used an ice-cream freezer for making an emulsion, by removing the can and adding a false bottom of 1-inch board to hold up the stirring gears. In fact, many different types of mixers can be constructed, depending on the material available and the scope of the work involved.

BOILED EMULSION.

Formula.

Paraffin oil	gallons	2
Water	do	1
Fish-oil soap	pounds	2
or		
Hard soap	do	1

Directions.—Put oil, water, and soap into a kettle or other vessel that will stand fire, and heat to the boiling point. While still very hot, pump the material (see fig. 16) into another vessel and then back again. Emulsion can not be made by this formula without a pump; stirring is not sufficient.

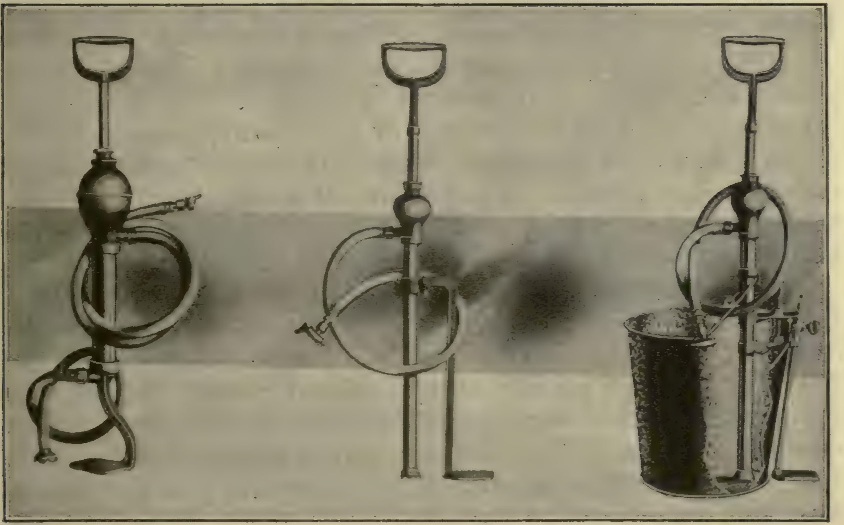

FIG. 16.—A pump used for emulsifying the oil. This is used in making the emulsions on a small scale. (Quaintance.)

Dilute to make 200 gallons of spray material.

For making the above formula the writer has used 9 and 15 gallon kettles, wash boilers, and 100-gallon oil tanks with uniform success.

If it is desirable to make this formula on a somewhat larger scale, the materials can be heated in a large kettle or other vessel and then dipped into a barrel pump outfit and the mixture emulsified by pumping it back upon itself. For safety it is best to have all the material pass through the pump twice, but it must not be pumped after it has become cool. Excessive pumping will break up a good emulsion. It can also be heated in a large galvanized oil tank having a capacity of 4 barrels and emulsified by means of the spraying machine. In this case the suction hose should be put into the tank of hot material and the discharge hose into the spray tank. For the second pumping, put the suction hose into the spray tank and the discharge hose into the storage barrels. When the spraying machine is used for this purpose, an old suction hose should be used, as well as a discarded piece of hose for the discharge end. This should be not more than 10 feet in length. The material should be run through an ordinary nozzle with the disk left off. The overflow will not emulsify this material.

At present this "boiled formula" is made by the Florence Villa Citrus Growers' Association and also the Tavares Association. These two plants are fitted with two 300-gallon tanks and the material is heated by steam. One association uses a large pressure pump with a 2-inch intake and a discharge of three-fourths inch. The material is pumped from one tank into another and then pumped over or back upon itself for about 10 minutes, and then it is barreled. This plant can make 3 barrels of emulsion in about 20 minutes. The other plant uses a water injector pump operated by steam.

Owing to the high temperature of the mixture, pumps used for emulsifying should have metal valves. If made of other material their period of usefulness is very short. It should always be remembered that a pressure pump must be used for emulsifying. The writer has never succeeded in making an emulsion with a rotary pump.

Difficulties that may arise in making the boiled formula are: (1) A lack of sufficient heat, (2) improper pumping, or (3) an improper emulsifier. In many tests the water and soap only were heated, and failure to produce a perfect emulsion resulted in every instance. On the other hand, when all the materials were heated together a perfect emulsion was secured. The materials should be heated until a slight foam or a few bubbles appear, but it is not necessary to boil for any length of time.

Some growers have failed because they attempted to stir the materials together with a stick, and others because they used a rotary pump. Neither of these is satisfactory.

The emulsifying agent is very important. There is no doubt that potash-fishoil soap is the most satisfactory of all soaps for the making of any of these emulsions. When this material is used the oil very seldom separates and the resulting emulsions never become too thick to be poured or handled conveniently. On the other hand, when hard soaps are used which are made from caustic soda and fats containing large proportions of stearin and small quantities of rosin, the emulsions separate on cooling, and will cause much trouble in mixing on the day after they are made. If the emulsion made from any hard soap found on the market is used on the same day that it is made no trouble will be experienced. The "cold-stirred" formula is difficult to make with hard soaps. The writer has found it impossible to make emulsions by using any of the soap powders, even if flour is used as a stabilizer.

Before any spray material is applied to a tree it should be tested to determine if it is a perfect emulsion. To do this, add a small amount to some soft water; if no oil floats or no thick, greasy scum forms, it is satisfactory. If free oil appears the emulsion is imperfect and should not be used. Great care should be used to stir the contents of the barrel thoroughly before any test is made.

The present price of potash-fishoil soap makes the "cold-stirred" formula somewhat expensive, but when the market becomes normal its cost will be reasonable. It has an advantage in that it will keep indefinitely and will not separate under ordinary conditions of temperature or usage. It has an added advantage in that no apparatus, other than an ordinary pail and paddle, is required for making it on a small scale.

Just at present the boiled-emulsion formula is the one which will appeal to the average citrus grower in Florida. It is, beyond all question, the cheapest effective insecticide for white flies and scale insects.

The oils used in the making of these formulas usually test from 24° to 32° Baumé and have a viscosity not less than 200. The best oils for spraying purposes have a viscosity of about 300 to 400 and they may be purchased from any of the oil companies operating in the citrus-growing belt. Petroleum fuel oil and distillate or gas oil may also be used and when applied should be used at twice the strength indicated for the lubricating oils. The soaps may be purchased from any grocery or fertilizer company.

PROPRIETARY MISCIBLE OILS.

There are several proprietary miscible oils on the market which the writer has found to give highly satisfactory results. These should be diluted so that the spray material will contain somewhere between $\frac{3}{4}$ per cent and 1 per cent of oil. The writer would advise the use of oil emulsions when diluted to about 1 per cent. Experience indicates that such substances as rosin oil and sulphuric acid should not be used in proprietary insecticides.

SPRAYS FOR RED SPIDERS AND RUST MITES.

It has been known for many years that sulphur sprays are successful against both rust mites and red spiders. Lime-sulphur solution is no doubt the best form of sulphur which has ever been devised for the control of these pests. The main value of this solution over other forms consists in its permanency, since after it once dries on the leaves it remains for a considerable length of time, whereas other forms are easily washed off by rain or dissipated by dew. Directions for making lime-sulphur solution are given in other publications of the department.[1] For these pests it is best to use lime-sulphur not weaker than 1 gallon to 75 of water. The maximum strength to be used will depend entirely upon the season of the year and what other objects the grower may have in view by spraying. This material *can not be used in combination with the oil sprays*, but it may be used in combination with the tobacco sprays for thrips in the bloom.

SODA-SULPHUR SOLUTION.

The main value of the soda-sulphur solution consists in the properties which enable it to be used in combination with the oil emulsions. Owing to the superiority of lime-sulphur solution the use of soda-sulphur solution alone is not advised. It has a distinct place, however, in forming a good combination spray for white flies, scale insects, and mites. It is made as follows:

Formula.

Flowers of sulphur	pounds	30
Caustic soda (98 per cent)	do	20
Water	gallons	20

To remove the lumps from the sulphur place a wire screen over the barrel and rub the sulphur through with the hands, then slowly add about 3 gallons of water and stir so as to form a thin paste. The caustic soda should then be added and the entire mixture stirred vigorously. Some growers add the caustic soda gradually to prevent too vigorous boiling, and others add it all at once with water enough to prevent too vigorous boiling. It is also practicable to dissolve the caustic soda in about 4 gallons of water before it is added to the sulphur. The boiling will be quite violent and it may be necessary to add a gallon or more of water during the process, but whether or not this is necessary can be determined by the operator.

The main difficulty in making this formula is that too great heat is generated, which liquefies the sulphur before it can be acted on by the caustic. If sediment forms this has been the cause. To prevent this excessive heat add more water in the beginning and during the process. After boiling has ceased add about 16 gallons of water.

For spraying against red spiders and rust mites use 1 gallon of this stock solution to 40 gallons of water. *When used with the oil sprays* the strength should be a little weaker than if used alone. When so used dilute 1 gallon to 50 gallons of water. If it is to be used in combination with oil emulsion it should be added to the tank or barrel of water before the oil emulsion.

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[1] Farmers' Bulletin 908, "Information for Fruit Growers about Insecticides, Spraying Machinery, and Important Insect Pests," by A. L. Quaintance and E. H. Siegler.

SOFTENING HARD WATER.

Whenever practicable the growers should use lake[1] water for spraying with the oil emulsions. When a proper emulsion is so used, no trouble will be experienced. If only deep well water or sulphur water is to be had for spraying purposes, some means must be taken to eliminate those chemicals which combine with the caustic soda in the oil emulsions to set the oil free. If such water is used without treatment, free oil sometimes appears on the surface, but usually a thick, greasy mass forms. Usually when sprayed on a tree the twigs are killed to a considerable extent. Some of these well waters are so hard that it requires an enormous amount of soap to soften them. Our experience indicates that caustic soda when used alone will not give satisfactory results. It has been found that if 1 pound of caustic soda per 100 gallons is used in addition to from 3 to 6 pounds of soap the oil emulsion will mix satisfactorily. Caustic soda should be dissolved in 2 or 3 gallons of water and then added to the full tank and the entire mixture stirred and left to stand about a minute. Before adding, the soap should have been dissolved at the rate of about 1 or 2 pounds per gallon of water. After the soda and soap solution have stood for 2 or 3 minutes the insecticide may be poured in.

It is advisable for the grower to proceed on a small scale at first, using a barrel of water or less. After the first addition of caustic soda and soap some insecticide should be added. If the thick, greasy scum forms within the period of 5 minutes, another test should be made, using a larger quantity of both caustic soda and soap.

FACTORS IN OBTAINING SUCCESSFUL RESULTS.

In order to obtain satisfactory results from spraying, the grower should carefully plan the operations a considerable time in advance.

PRELIMINARY CAMPAIGN.

If it is the intention to purchase a spraying outfit, one should be ordered at least two months before it is needed. If a spraying outfit is already at hand, great care should be taken to overhaul it most thoroughly at least a month before spraying begins. This will afford plenty of time to send for parts, if any need to be replaced. The tank should be cleaned out carefully, and soaked so that it will not leak. The pump should be carefully repaired, and if any parts are worn out or broken they should be replaced. It is essential that the valves be in perfect condition and these should be carefully polished with emery dust or emery cloth. The valve seats if worn should be changed, or new ones substituted. It may be that these can be reamed out by a machinist. In case any gears are badly worn, new ones should be obtained. The engine should, likewise, be carefully gone over to see that it is ready for operation. If the cut-offs leak they should be replaced or ground, and the nozzles and rods should be carefully examined. In regard to the hose, it is always advisable to have an extra lead, so that in case those in use leak badly the spraying can proceed without delays.

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[1] It may be explained that owing to limestone formation in Florida, well water is usually "hard."

The insecticide or insecticide material for the entire grove should be on hand at least a week or 10 days before operations are to be begun. It is advisable that the quantity be carefully estimated, and it is better to overestimate a little than to underestimate the quantity, as in the latter case the spraying operations would have to cease until another supply could be obtained.

The source of water supply is also very important. For the oil emulsions it is much better to use lake water, but if this is impossible the water from the deep wells can be used and treated as heretofore suggested. If sulphur sprays are to be used alone they will mix satisfactorily with both lake and deep well water. Wherever practicable the water should be hauled to the machine by a supply team (fig. 13). Where two leads of hose only are being used, this hauling can be done with one horse and a boy with two barrels, unless, of course, the water supply is at a very great distance away. When four leads of hose are being used, it will be necessary to use a double team and four barrels or a supply tank. If the water for spraying is hauled to the machine, instead of going to the water supply with the machine, the number of trees sprayed can be practically doubled. In our operations we have sprayed as many as 18 loads of 200 gallons each in 10 hours. When the water is hauled to the machine the tank filler or suction pipe may be inserted into one barrel while the spray men, with buckets, dip the other three barrels into the tank. This saves much time in filling.

Before any insecticide is used its strength should be known in order to permit the dilution of the spray to the proper strength. In case of the oil emulsions these should be diluted according to the percentage of oil they contain. The sulphur solutions should be diluted according to the quantity of sulphur in each gallon of liquid, which is usually told by the degree of density as determined by the hydrometer.

It is also of considerable convenience to be able to open a barrel in the proper manner without breaking in the head. To do this take an ax or other implement and pound first on one side of the bung and then on the other. After a few such strokes the bung will be loosened so that it can be very easily removed or "jumped" out. After this is done a paddle should be inserted through the bunghole to stir the insecticide. The insecticide should always be stirred before any is taken out for spraying. It is convenient also to nail a small piece of tin on one side of the bunghole which will act as a spout and cause the insecticide to run into the measuring bucket instead of down the side of the barrel. A hole also can be bored in the head about 1 inch from the edge on that side of the barrel which is opposite the bunghole. A faucet or molasses gate should then be inserted in the hole, and the barrel placed on its side with the faucet next the ground. The bung should then be removed to permit stirring and entrance of air. A stick can be used for this purpose. The best way to mix an insecticide is to draw off several buckets full through the faucet and pour back through a funnel in the bunghole.

SPRAYING PROCEDURE.

HOW TO APPLY THE SPRAY.

In spraying for the control of white flies and scale insects the method of application is the same whether a barrel pump or a power outfit be used. The object should be the complete wetting of both the upper and lower surfaces of the leaves as well as all the limbs and the trunk.

In applying the spray the operator should begin on the far side of the tree and work around to the point nearest the machine. The second half of the tree should be handled in like manner. If two operators are at work on the same tree they should both begin at the point farthest from the machine and proceed until they meet.

The spray should be applied to the tree in a systematic way. The operator should begin at the base and work to the top, inserting the rod among the branches so as to spray the center of the tree. The entire tree may be thus sprayed in sections, the operators proceeding alternately from the bottom to the top and from the top to the bottom. To prevent kinks in the hose, the operator in moving from tree to tree should never make a complete turn. In case kinks appear they should be immediately taken out by turning the spray rod and not by pulling the hose. In pulling kinks out of hose the hose fabric is destroyed. Such an avoidable waste of property should not be permitted.

PRESSURE.

The pressure that should be maintained depends to a considerable extent upon the agility of the man using the rod. If a man moves rapidly, a greater pressure can be maintained without accompanying loss of material than when a man moves slowly. A slow man will not be able to handle a much greater pressure than 150 pounds, whereas an active one will handle 250 pounds. It is very doubtful if a slow-moving man should be employed to use a spray rod. The pressure also depends upon the size of the hole in the disks. The smaller the hole, the greater must be the pressure to furnish sufficient spray material to wet the foliage without losing time. If a barrel pump is used, from 80 to 100 pounds will be all that can be held with one man pumping. From 100 to 125 pounds will be all that can be maintained when the large lever pump is used with one man pumping. For average conditions the power outfit should maintain from 175 to 250 pounds. When the pressure is less than 175 pounds operations should cease.

QUANTITY OF LIQUID REQUIRED TO WET TREES.

Successful results can not be obtained unless sufficient material is used to wet the foliage completely. To a certain degree the quantity of liquid used is a good criterion of the efficiency of the spraying done. We have known intelligent grove owners to use a gallon of material for a tree 10 feet high. No satisfactory results can be expected from such spraying. The quantity to be used will depend upon the density of the foliage as well as upon the size of the trees. Small trees having dense foliage require much more material than do larger trees with more sparse foliage and straggling branches. For trees one or two years old one-half to three-fourths of a gallon is sufficient. Trees 3 to 4 years old should require from 1 to 1½ gallons, and trees just beginning to bear should seldom receive less than 2 gallons per tree. Trees of large spread and 10 feet in height sometimes require as much as 10 gallons, while the very largest trees require as much as 15 gallons. The average tree of 10 to 12 feet requires about 8 gallons.

RAINS AND DEWS.

Spraying should never be done during a rain or when the foliage is dripping wet. Spraying under such conditions dilutes the spray to such an extent that it is entirely ineffective in killing the pests. Operations should cease at least 10 minutes before a shower is about to fall, in order to give the spray a chance to dry. After a shower operations should be resumed in 20 to 30 minutes, or after a large part of the drip has ceased. If heavy showers fall late in the afternoon it is improbable that spraying resumed the same day will be effective. It is seldom that the dew is so heavy as to prevent spraying at 7 o'clock in the morning.

THOROUGHNESS.

In spraying for any pest on citrus trees the complete wetting of every leaf on both surfaces as well as the branches and trunk should be accomplished. It is only when leaves are hit by the spray that the pests on them are killed. Lack of thoroughness in this respect is responsible for more failures to obtain satisfactory results than are all other factors combined.

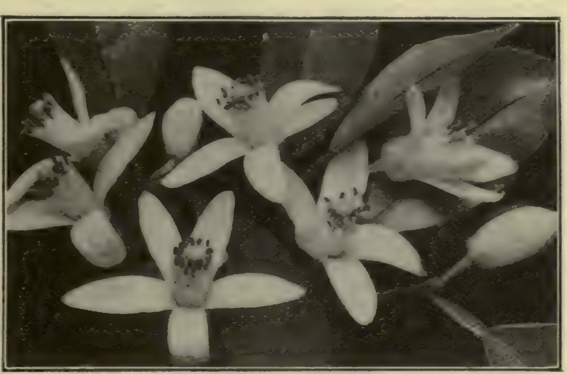

FIG. 17.—Normal orange blooms and buds. Compare with the bloom in figure 18.

In order that satisfactory results may be secured, only the most intelligent, honest, and careful laborers should be employed to handle the spray rods. In fact, it might be well for the foreman or owner to handle one rod. If this is not practicable, the owner or a responsible foreman should be with the machine all the time. It is also advisable to examine the leaves frequently to see if they have been hit on the lower surfaces. The sprayer himself should have an opportunity to examine his own work. Even when the best and most thorough work has been done, many leaves will remain untouched by the spray.

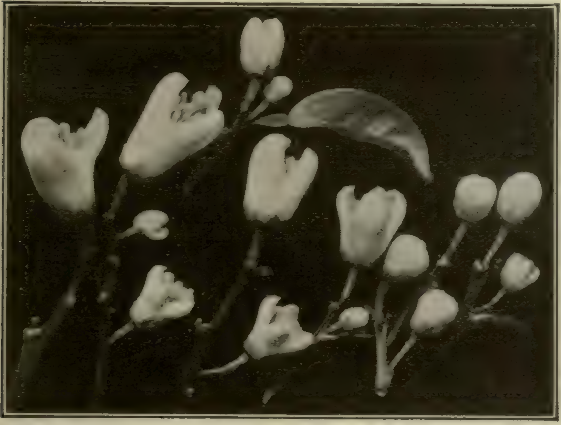

FIG. 18.—Spraying with heavy oil emulsions at full strength may injure the bloom of orange and grapefruit, as here illustrated, and cause much of it to drop.

WHEN TO SPRAY.

So far as the effect of the various insecticides on the trees and fruit is concerned it is reasonably safe to spray at any season of the year. The oil emulsions, however, should not be used at more than half strength during the blossoming period (compare figs. 17 and 18) or until the fruit is about an inch in diameter. Although the writer has known several people to use them at this season at full strength without any injurious results, the application of oil sprays to the blossoms is too hazardous to be generally practiced. When low temperatures follow the application of oil sprays, an excessive shedding of foliage usually occurs. Spraying operations that are being carried on during the winter should be discontinued as soon as a cold wave is predicted. The sulphur sprays, either alone or in combination with the tobacco solutions, usually will cause no damage to the blossoms if used at any recommended strength. Neither will the tobacco solutions cause any damage to the blossoms even if used at several times the recommended strength. If it is the intention to spray during the winter, it will be found much more convenient to spray after the fruit has been removed. The insecticide usually will do no harm to the fruit, but the spraying operations may cause more or less mechanical injury when the branches are heavily laden with fruit. It is also difficult to do as thorough work when the branches are weighted with fruit.

So far as the effectiveness of the various insecticides on the different stages of the insects and mites is concerned, it is about as great at one time as at another. The white flies and scale insects can be killed both in the summer and during the winter, either in the mature or in the immature stages. The mites also can be killed at any time they may be present.

The life history and habits of nearly all pests on citrus trees are, fortunately, such that good and satisfactory results can be obtained at any time the spray is applied, but to obtain the maximum benefit with the minimum expense the spraying must be opportune. Much of the spraying done at present brings no returns to the grower, because it is done after the damage has taken place. The writer has seen many groves being sprayed when the purple scale had already done $2 worth of damage per tree. Men also have been seen spraying where the pests were so few that practically no beneficial results would ever follow the treatment. *The spraying for rust mites is often done when not more than two or three mites can be found on a fruit, or after they have become so numerous that the russeting has already appeared and could not be prevented by any amount of spraying.*

As a general rule, the time to spray for the control of pests on citrus trees is when they are present in such numbers that if left to reproduce without artificial hindrance they would soon become injurious. The pests should not be allowed to increase to a point where they attract noticeable attention, as in figure 19. In case the various pests of citrus trees are permitted to become so abundant as to cause damage, the profits which might be derived from artificial treatment, such as spraying, are to a certain extent lost.

Specifically then, what should guide the citrus grower in deciding just when spraying should be done or if it should be done at all? It must be confessed that it is most difficult to answer such a question. This difficulty arises from the fact that the extent of the future infestation of any pest is so influenced by weather conditions and natural enemies that it is impossible to make predictions approximating any degree of accuracy. A few suggestions are given here to help the intelligent grower to handle this most difficult of all problems.

Six-spotted mite.—In the control of the six-spotted mite spraying should be done if one or two trees are badly infested in March, April, or May, or if many trees are slightly infested. This pest spreads most rapidly in the dry spring months, and complete defoliation often follows while the grower is contemplating spraying. After the rainy season sets in trouble is rarely experienced with this species.

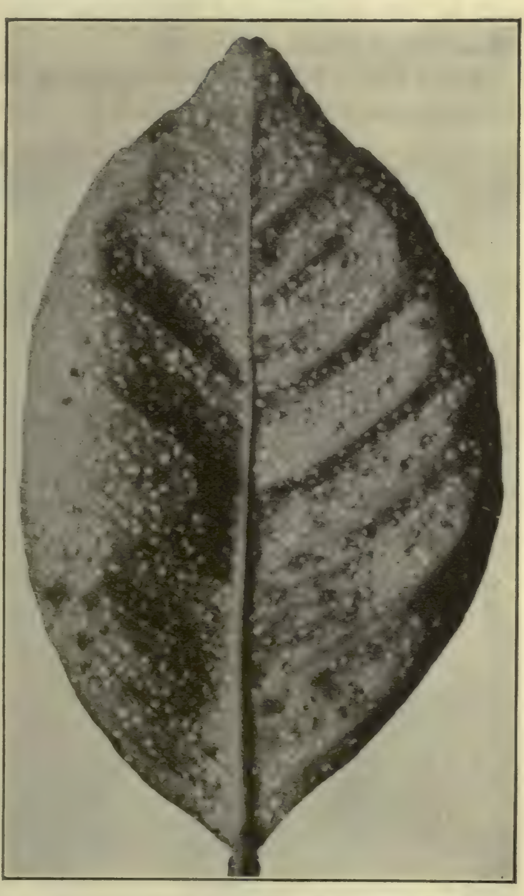

FIG. 19.—An orange leaf heavily infested with the citrus white fly. There are over 800 pupæ and pupa cases on this leaf. The white fly should never be permitted to become as abundant as here shown. (Morrill and Back.)

Rust mite.—The rust mite, being of small size, often reaches the maximum infestation before the growers know of its presence. The first intimation of its presence is evidenced by the "russet" fruit, and then it is too late to remedy the damage. The grower should provide himself with a hand lens to enable him to see this serious pest. If there are about 50 mites on each of the old leaves in the spring, spraying should be done within the next few days. Another rule to follow is to spray when the mites are abundant on the foliage and just beginning to appear on the young fruit. If the fruit is about 1½ inches in diameter and a few fruits per tree look a little brownish, the time is short before spraying should be started to get bright fruit. If in the spring of the year, in either April, May, or June, from 100 to 200 mites are on each fruit, spraying should be given within the next two weeks. At other times a greater number could be present without russeting the fruit.

Scale insects.—For scales spraying should be done before any of the limbs or branches are killed or any of the leaves have turned yellow. No trees should be left until the center is killed out before treatment is given.

White flies.—The object in spraying for white flies should be to keep the sooty mold (figs. 20 and 21) from both the leaves and fruit. When each leaf has an average of from 6 to 10 pupæ in the spring, spraying should by all means be given in May. Unless the grower has acquired considerable judgment as to when spraying should be done, it might be well to follow some such scheme as here given.

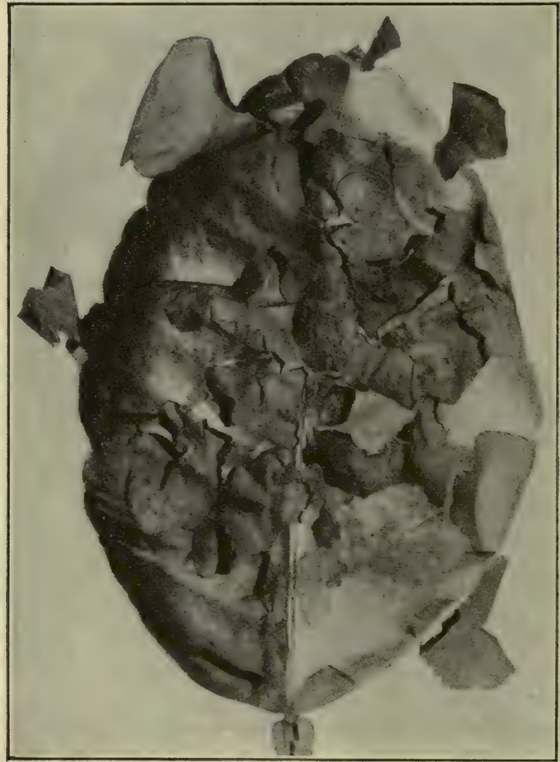

FIG. 20.—Miscible-oil sprays cause the sooty mold following white-fly attack to break and fall from the foliage and branches. A strong breeze or heavy rain two or three days after trees have been sprayed usually will take off all or nearly all the smooty mold from the tree. (Morrill and Back.)

SPRAYING SCHEDULE RECOMMENDED.

The following spraying scheme has been used extensively for four years and generally has given satisfactory results. No hard and fast scheme can be given, however, and the number of sprayings depends to a large extent on the thoroughness of the work and the abundance of the pests.

1.—Paraffin-oil emulsions: Government formula, 1 per cent of oil—May: The main object of spraying at this time is to kill white flies, scale insects, and to a large extent rust mites, although this treatment must not be relied upon to control the last pest. The spraying should be given after the adults of the first brood of white flies have disappeared and before the appearance of those of the second brood. The fruit should be an inch or more in diameter. This treatment should be given before the beginning of the rainy season, so that the beneficial fungi will attack those insects which are not killed by the spray.

2.—Lime-sulphur solution, 32° Baumé, 1–50 to 1–75—June to July: The main object of this treatment is to kill rust mites, and the best time for its application varies with the appearance of the maximum number of rust mites. It should be applied before the mites get very abundant and before russeting appears. It will also kill some scales and white flies, but is of little value for that purpose.

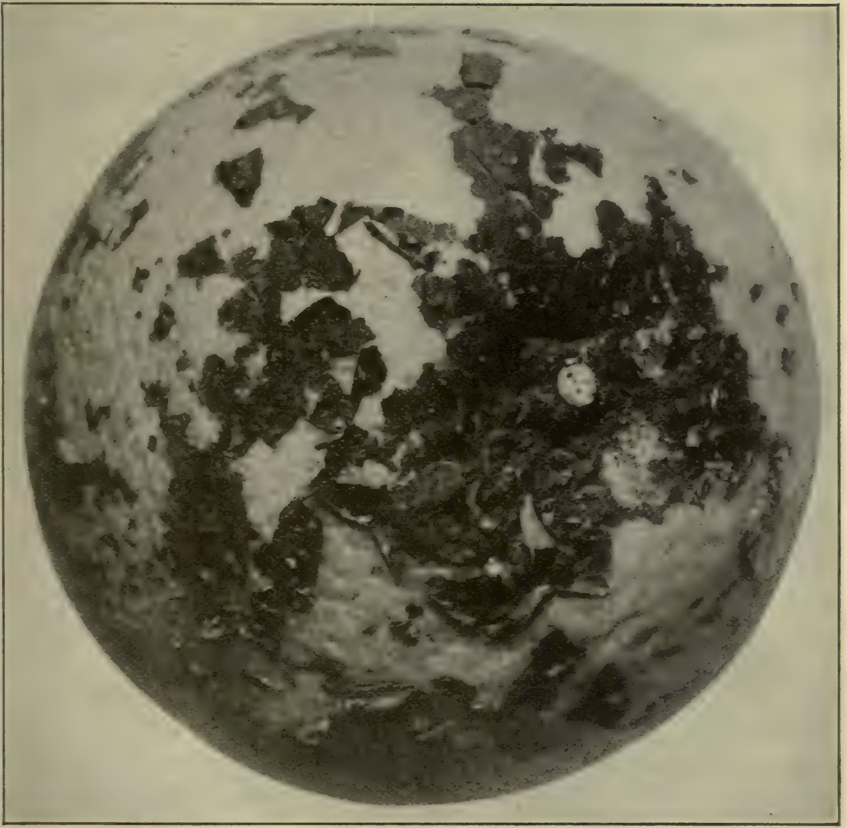

Fig. 21.—Heavy coatings of sooty mold on oranges and grapefruit prevent the fruit from coloring normally. The rind remains green beneath the layers of sooty mold. Spraying with a miscible oil breaks up the sooty mold as illustrated, thus giving the sun a chance to color the fruit.

3.—Paraffin-oil emulsions: Government formula, 1 per cent of oil—August 25 to October 31: This is the second spraying for the white fly and scale insects. The object of spraying at this time is to kill all the white-fly larvæ which are the progeny of the third and last brood. It is this brood which causes nearly all the damage from the white flies, and the earlier they are killed the better it is for the tree. This will also remove the sooty mold from the leaves (fig. 20) and from the fruit (fig. 21) so that the sun can color the fruit. Soda-sulphur, 1–50, may be added to this spray to increase its effectiveness in killing rust mites.

4.—Lime-sulphur solution, 32° Baumé, 1–50 to 1–75—November or December: The object of this spraying is to kill rust mites, and it may or may not be necessary, depending on the abundance of the mites.

It may be necessary to spray for rust mites and red spiders before number one is given. This is especially true for grapefruit in the more southern counties of Florida. If such a spraying is given, it should be given in the midst of the blossoming period, using lime-sulphur 1–40, which will kill rust mites, red spiders, and young scales. It is advisable to add nicotine sulphate 1–1,200 if thrips are abundant. It may also be necessary to spray three times with the oil sprays, in which case this treatment can be given in midsummer or in winter. If the red scale is very abundant, two sprayings with the oil emulsions should be given at intervals of about a month.

THE EFFECT OF INSECTICIDES ON PESTS.

The fish-oil soap and the oil sprays kill the insects by asphyxiating them. The oil sprays kill the adults, eggs, larvæ, and pupæ of the white flies. It is not difficult to determine whether the larvæ and pupæ of the white flies have been killed, for they turn brownish 3 to 10 days after the spray has been applied. (Fig. 22.) They also brush from the leaf easily. A month or more afterwards those which have been killed are quite brown and somewhat dried up.

The oil sprays kill all stages of the purple scale, and in many cases all the eggs of some females are prevented from hatching. In other cases the oil enters the opening in the rear of the scale covering and prevents a row or two of eggs nearest the opening from hatching. In the natural course of events the eggs nearest the opening hatch first, since they were deposited first. This gives those young scales that hatch from eggs farther from the opening plenty of opportunity to emerge. When the first row or two of eggs is prevented from hatching, the exit is stopped. This prevents those young scales from emerging that hatch from eggs not affected by the oil film. Thus almost complete mortality results.

The oil spray kills the young stages of the red scale and in most cases the adult females, but the scale covering is fastened so closely to the leaf or fruit that the eggs are seldom harmed. A second spraying must be given after these hatch and develop into the young stages.

The sulphur sprays are extremely effective in killing rust mites. The action is rapid, the bodies of the mites being largely destroyed by the caustic nature of the spray. When on the fruit, a few are washed to where the drop of spray collects and there their dried bodies may be seen after the spray has evaporated. The eggs also are killed if the spray is used at the recommended dilutions.

The sulphur sprays are very effective, also, in killing the purple and six-spotted mites. The killing action is rapid, but the bodies are not completely destroyed by the caustic nature of the spray as is the case with rust mites. The spray does not prevent the eggs from hatching, but the presence of the spray usually kills the young mite as soon as it emerges from its eggshell. Thousands of newly hatched dead mites have been observed near the eggshell from which they had just emerged. While the oil sprays usually prevent an egg from hatching, the sulphur sprays more often kill the young "crawler" as soon as it hatches.

Sulphur when used in a fine state with hydrated lime also kills six-spotted and rust mites. When six-spotted mites come in contact with fine sulphur they become exceedingly active at first, run about in a perfectly wild and aimless manner, then gradually become quiet, and finally die. All mites, so far as known, are extremely sensitive to sulphur in any form.

SPRAY INJURIES.

Under average conditions of temperature and moisture the oil sprays will not cause any noticeable injury to either the foliage or the fruit. New growth often starts in a few days after the killing of the insects. A large percentage of old leaves, now functionless, fall about the third day following the application of an oil spray. Good leaves very seldom fall. In the experiments 2 per cent of oil,

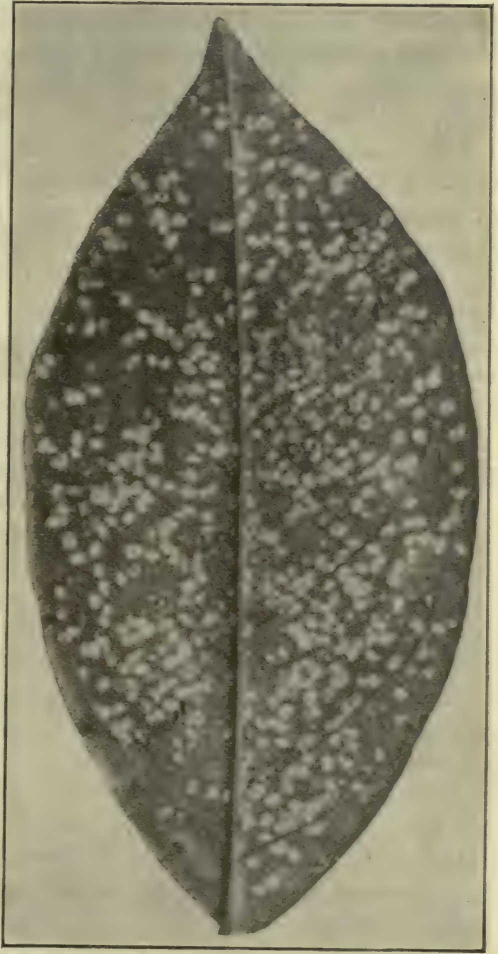

FIG. 22.—Pupæ of the citrus white fly. When living the pupæ are seen with difficulty, but after they have been killed, as in the illustration, they turn brown and one can then easily see how thin and scalelike they really are. (Morrill and Back.)

or twice as much as required, has been used extensively without causing normal leaves to fall prematurely. In small tests 3 per cent of oil in the diluted spray material caused no damage. No injury follows spraying either before or during a rain and neither does humidity appear to be a factor in causing injury. When the oil emulsions are used, whether made of kerosene or heavy lubricating oil of 24° Baumé, shadows sometimes appear on the fruit. These shadows usually follow spraying during hot, bright days when the temperature is above 91° or 92° F. As the temperature is very high, the heat evaporates the water in the spray material before it has had time to run off. This concentrates the oil in one spot and causes a slight damage to the stomata, resulting in a darker shade of green than the surrounding area. These dark-green shadows disappear not later than a week or two after the fruit has colored in the fall and it is impossible to locate the previous discolorations if these have not been marked. Sometimes the damage is localized to the spot where the drop of spray has collected. The only way to avoid such damage would be to cease spraying when the temperature rose above 92°. This injury occurs only occasionally.

The application of the oil sprays two or three times a year at the recommended strength has never been known to cause devitalization of the trees. If an excessive amount of spray is used the normal growth of the leaves is interrupted. They do not reach the proper size, become thin, and the tree has the appearance of being stunted. The fruit also is small, does not color up properly or at the proper time, and is sour when other fruit is sweet. Such a condition only follows the application of from three to six times as much oil as the worst infestation of white flies and scale insects requires. Two applications within one month of a 2 per cent solution in 1916 did no noticeable damage to either the tree or the fruit.

Soda-sulphur solution very seldom, if ever, causes any damage to the trees or fruit. No accumulated ill effects have been known to follow the use of this spray. This noninjuriousness is no doubt due to its lack of stability since it is easily washed off by rains and dissipated by dews.

Lime-sulphur solution does not cause damage at the recommended dilutions under average conditions. When the temperature is 92° F. and the sun is bright, injury to the fruit sometimes follows, but this does not often occur. In all the experimental work such injury followed on only one occasion. The injury is always located on the side of the fruit turned to the sun at the particular time of day when the spraying was done. The exact cause of this type ot injury is not yet fully understood, but it is very certain that it should not be considered as being due to the insecticide alone, but to the combined action of the sun and the insecticide. When the injury is caused by the insecticide alone. the blemish will be found at places where the drop of spray collects on the lower surface of each fruit.

Instead of injuring citrus trees, lime-sulphur solution has a stimulating effect. The leaves become a darker green and the fruit reaches a larger size. Fruit has been known to ripen at least three weeks to a month earlier than other fruit of the same kind in an adjoining row. The exact cause of this is not known, but the spray evidently has some direct action on the leaves. Careful experiments have shown that there is no known spray so beneficial to citrus trees as is lime-sulphur solution.

COST OF SPRAYING.

The cost of spraying (Table I) necessarily varies and depends upon the size of the trees, the density of the foliage, the equipment used, and the nearness of the grove to the water supply. Accurate estimates of the probable cost can be computed only after all these factors have been taken into consideration. Nursery trees can be sprayed for one-sixth of a cent each, while the largest trees will cost as much as 10 cents. Trees with dense foliage require much more insecticide and a longer time to spray than those with sparse foliage, even though the latter may be much larger trees. If the spraying is done with a barrel pump the cost will be somewhat greater than if done with a power outfit. The item of labor will be not far from 75 per cent of the total cost. If the water supply is in the grove or very close, the cost will be considerably less than if it is some distance away. A water supply a greater distance away than half a mile is not practicable, because it would require two extra teams to supply one machine. This would increase the cost about 1½ cents per tree.

In computing the cost of spraying the depreciation of machinery should always be included. Many inquiries were sent to citrus growers for information on this point. Some estimated the depreciation to be as great as 25 per cent. One grower thought it would be as low as 10 per cent, but it was the opinion of the majority that from 15 to 20 per cent would be more consistent. This appeals to the writer as the proper estimate to be placed upon this phase of the cost of spraying. The percentage of depreciation will depend almost entirely upon the care that is given the machine. The length of time a machine will be serviceable depends much more upon the care it receives than upon the amount of work it does.

The writer has obtained from many growers the actual cost figures for spraying done on a commercial basis under the average grove conditions prevailing in Florida. These will assist any grower contemplating a spraying program in arriving at an accurate estimate of the probable cost. These statements include the depreciation of machinery as well as cost of labor, team hire, insecticides, and incidentals, but naturally can not be construed to apply to such unusual conditions as those bearing on a local shortage in chemicals due to unprecedented freight congestion, or to a deficiency in the supply of the chemicals in the United States generally.

TABLE I.—*Cost of spraying.*

Grove No.	Size of trees in boxes of fruit.	Acres.	Number of trees.	Applications per year.	Cost.			Distribution of cost.			Incidentals.	Remarks.
					Per box.	Per tree.	Per acre.	Insecticides.	Labor.	Team.		
								P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	
1	10	7½	450	7	......	0.50	$30.00	......	......	......	......	
2	12	......	4,316	1	......	.097	......	34	29.4	32	4.5	
3	12	......	1,239	3	0.0267	.109	......	26	28	35	11	
4	15	......	300	5	.050	.66	......	......	......	......	......	
5	8	10	650	2	.056	......	11.00	40	......	......	......	
6	10	260	......	5	.0438	......	......	......	......	......	......	
7	10	......	6,367	5	......	.21½	......	46	......	......	......	
8	10	10	650	3	......	.21½	14.00	48	......	......	......	
9	10	260	......	5	.06	......	......	50	......	......	......	
10	7	300	......	......	.06	......	......	......	......	......	......	
11	8	......	1,000	1	......	.08	......	......	......	......	......	
12	8	40	......	4	.055	......	......	......	......	......	......	
13	10	550	......	1	......	......	3.00	......	......	......	......	
14	18	35	......	6	.05	......	......	......	......	......	......	
15	10	......	1,909	1	......	.08	......	44	35	21	......	
16	10	......	1,800	1	......	.083	......	......	......	......	......	
17	8	60	......	4	.05	.16	......	......	......	......	......	
18	8	120	6,360	4	.06	.20	......	64	36	......	......	
19	8	20	1,600	1	......	.06	......	45	55	......	......	
20	8	......	2,125	1	......	.08	......	57	36	......	7	
21	8	......	1,343	1	......	.78	......	24	65	......	11	
22	6	......	......	3	......	.15	......	......			......	
23	......	......	400	1	.022	.76	......	19	68	13	......	Hand pump.
24	5	......	778	3	......	.194	......	36	61	......	......	1914 pump.
25	5	......	778	3	......	.20	......	27	73	......	......	1915 pump.
26	7	......	500	1	.29	......	......	25	35	30	......	

The figures of Table I show that it will cost from $3 to $5.50 per acre per application to spray the average bearing grove. The cost per box is also seen to be from 1 to 1½ cents for each application and the cost per tree from 5 to 10 cents. To carry out any annual spraying schedule it will cost about 6 cents per box, 20 cents per tree, and about $15 per acre. The cost of spraying young trees is very small. One nurseryman sprayed 40,000 trees with the oil spray for less than one-sixth of a cent each. Young grove trees from 1 to 3 years old can be sprayed for about 1 cent each.

PROFITS FROM SPRAYING.

After many years of work it is still impossible to express the percentage of profits to be expected on money expended in spraying for the control of citrus pests. This same condition, however, applies to every grove operation in Florida. The profits which may arise from following a spraying schedule are due to the raising of the grade of the fruit and increasing the yield by preventing the devitalization of the trees following insect attack. (Compare figs. 23 and 24.) A detailed statement of the profits a grower should expect from spraying has been published in Department Bulletin 645, "Some Reasons for Spraying Citrus Trees in Florida," and the reader is referred to that publication for the complete discussion of this phase of the spraying question.

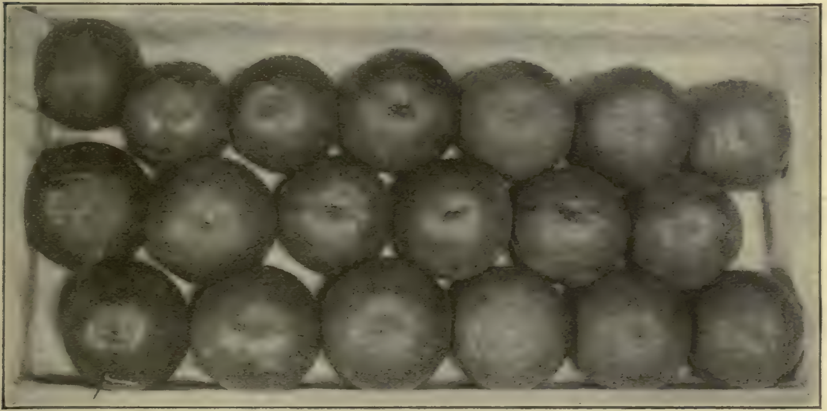

FIG. 23.—A miscellaneous lot of fruit picked from trees sprayed to kill rust mites. Only 19 fruits could be packed in the tray. Compare fruits shown in figure 24.

In that bulletin it was shown that in the 1915–16 citrus crop there was a loss of over $500,000 due to the lowering of the grades of the fruit, caused by pests, which could have been prevented very easily. The reduction in size caused an additional loss of $475,000, and the reduction in yield caused a loss of $760,000, making a total of $1,744,955, practically all of which could have been prevented easily at a nominal cost. To spray this crop at 6 cents per box would have cost $456,000, leaving a profit of $1,288,955, or 282.7 per cent profit on the investment.

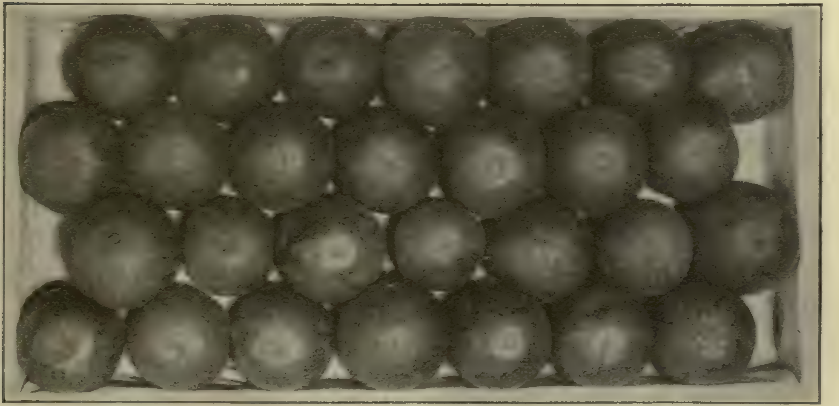

FIG. 24.—A miscellaneous lot of oranges from unsprayed trees adjoining sprayed ones. Note that these 28 fruits take up the same space as the 19 fruits from sprayed trees shown in figure 23. Spraying increases the size of the fruit.

In addition to these profits there are benefits that can not be expressed in a money unit. The better the fruit, the greater its marketability. High-grade fruit can be sold when the owner desires to sell it; the lower grades can be sold when the buyers want it, or when the market calls for the lower grades. Many growers consider this a most important item. There is much satisfaction in growing fine fruit and owning healthy trees. This makes orange growing fascinating.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO INSECTS INJURIOUS TO CITRUS AND OTHER SUBTROPICAL FRUITS.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Control of the Citrus Thrips in California and Arizona. (Farmers' Bulletin 674.)
Carbon Disulphid as an Insecticide. (Farmers' Bulletin 799.)
Common Mealybug and its Control in California. (Farmers' Bulletin 862.)
Fumigation of Ornamental Greenhouse Plants with Hydrocyanic-acid Gas. (Farmers' Bulletin 880.)
Fumigation of Citrus Trees. (Farmers' Bulletin 923.)
Control of the Argentine Ant in Orange Groves. (Farmers' Bulletin 928.)
Spraying for the Control of Insects and Mites Attacking Citrus Trees in Florida. (Farmers' Bulletin 933.)
Citrus Fruit Insects in Mediterranean Countries. (Department Bulletin 134.)
The Mediterranean Fruit Fly in Bermuda. (Department Bulletin 161.)
Argentine Ant: Distribution and Control in the United States. (Department Bulletin 377.)
The Citrus Thrips. (Department Bulletin 616.)
The Mediterranean Fruit Fly. (Department Bulletin 640.)
Some Reasons for Spraying to Control Insect and Mite Enemies of Citrus Trees in Florida. (Department Bulletin 645.)
The Argentine Ant in Relation to Citrus Orchards. (Department Bulletin 647.)
Preparations for Winter Fumigation for Citrus White Fly. (Entomology Circular 111.)
Spraying for White Flies in Florida. (Entomology Circular 168.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

Katydids Injurious to Oranges in California. (Department Bulletin 256.) Price, 10 cents.
The Melon Fly in Hawaii. (Department Bulletin 491.) Price, 25 cents.
Fumigation of Ornamental Greenhouse Plants with Hydrocyanic-acid Gas. (Department Bulletin 513.) Price, 5 cents.
The Mediterranean Fruit Fly in Hawaii. (Department Bulletin 536.) Price, 30 cents.
Mango Weevil. (Entomology Circular 141.) 1911. Price, 5 cents.
Fumigation for Citrus White Fly, as Adapted to Florida Conditions. (Entomology Bulletin 76.) 1908. Price, 15 cents.
Fumigation Investigations in California. (Entomology Bulletin 79.) 1909. Price, 15 cents.
Hydrocyanic-acid Gas Fumigation in California. (Entomology Bulletin 90, 3 pts.) 1913. Price, 20 cents.
Fumigation of Citrus Trees. (Entomology Bulletin 90, pt. I.) 1913. Price, 20 cents.
Value of Sodium Cyanid for Fumigation Purposes. (Entomology Bulletin 90, pt. II.) 1913. Price, 5 cents.
Chemistry of Fumigation with Hydrocyanic-acid Gas. (Entomology Bulletin 90, pt. III.) 1913. Price, 5 cents.
White Flies Injurious to Citrus in Florida. (Entomology Bulletin 92.) 1911. Price, 25 cents.
Orange Thrips, Report of Progress. (Entomology Bulletin 99, pt. I.) 1911. Price, 5 cents.
Red-banded Thrips. (Entomology Bulletin 99, pt. II.) 1912. Price, 5 cents.
Natural Control of White Flies in Florida. (Entomology Bulletin 102.) 1912. Price, 20 cents.

CONTROL OF THE ARGENTINE ANT IN ORANGE GROVES

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FARMERS' BULLETIN 928

UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. March, 1918

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SEVERAL VERY INJURIOUS scale pests of orange would be much more largely controlled by their insect enemies were it not for the Argentine ant.

This ant is very fond of the sweet substance, known as honeydew, excreted by mealybugs and other soft scales and is always very attentive to them and prevents many of their insect enemies from approaching them. Thus the natural enemies of these pests are hindered in carrying on their good work. As a result, some of the soft scales become excessively abundant.

The Argentine ant does not obtain honeydew from the armored scales, but in patrolling the trees constantly in large numbers in search of insect prey it hinders, to a certain extent, the work of the natural enemies of these scales, and if the control of the scales be neglected for several seasons the infestation may be considerably increased.

In Louisiana orange groves this ant can be controlled as an orchard and house pest by the trapping method described on pages 12–17. Once the orchard has been practically rid of ants, which can be done in from 8 to 10 fumigations of the trapped ants, little work will be needed to keep them from causing further annoyance.

In California orange groves the ants can be prevented from getting into the trees by banding the trees in accordance with the instructions on pages 19–20, and their numbers can be reduced by poisoning. Recipes for ant poisons and directions for using them are given on pages 17–19.

CONTROL OF THE ARGENTINE ANT[1] IN ORANGE GROVES.

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INTRODUCTION AND IMPORTANCE.

THE ARGENTINE ANT was introduced first into the United States on ships arriving at New Orleans from tropical American ports. It has been known in New Orleans for at least 25 years, and probably has been reintroduced many times during that period. It made its way from Orleans Parish into Plaquemines and St. Bernard Parishes, along the lower Mississippi River, by rail and on coal barges, and now occurs in slightly more than one-fourth of the orange groves of Louisiana. It has become established widely in California orange orchards, and is especially numerous in some orchards in Los Angeles and Riverside Counties.

This ant is of first importance as a pest in houses, groceries, and candy and meat shops. It not only causes great annoyance by persistently getting into all foods containing sugar, fats, or fruit juices, and into meat, but sometimes gets into beds and into the mouth and nostrils of infants. It probably ranks near to the house fly as a disease carrier, as it is a frequent visitor at feces and other sources of infection and doubtless often nests in contaminated soil.

It has been rated as a very important pest of field and truck crops, on certain of which it is said to cause great increase of mealybugs and aphids. Sometimes it removes the seeds of certain kinds of vegetables from the ground before they have germinated, necessitating resowing and protection of the seed. The ant also has been a pest at times in greenhouses, where it occasionally cuts into certain flowers and fosters mealybugs and aphids.

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[1] *Iridomyrmex humilis* Mayr.

The general belief has been that in Louisiana the ant caused far more serious damage to the orange trees than to any other crop. It was thought to bring about a tremendous increase of all orange-infesting scales, white flies, and aphids, to destroy the blossoms and branches, injure the roots, greatly reduce the crop, and even kill the trees. In reality the ant is responsible for only one form of direct injury to orange trees. Rarely it chews into the petals and stamens of open orange blossoms for the purpose of squeezing out the sap. This occurs only on isolated trees, where food is scarce in comparison with the number of ants, and the amount of injury resulting is unimportant except on rare occasions. The ants habitually visit orange and other flowers to obtain nectar and to capture flower-feeding insects, but ordinarily do no damage to the flowers. The ant does not and can not injure sound oranges, although it enters and feeds upon the juice of broken ripe or rotting fruits.

The chief importance of the Argentine ant in orange groves is due to the fact that certain injurious scale insects become much more abundant as a result of its presence, and that it fosters mealybugs and aphids.

HOW THE PRESENCE OF THE ARGENTINE ANT FAVORS INCREASED INFESTATION BY SCALE INSECTS.

Two very distinct groups, or classes, of scale insects infest orange trees: (1) The armored scales, or those which settle permanently in a particular spot, lose their legs, and form a protective covering, such as a scale or shell, over the body. The eggs are deposited and the young hatch under the protection of this shell. The hard, flattened, apparently lifeless particles encrusting the branches and trunk and sometimes the fruit and leaves of orange trees are the armored scales. (2) The unarmored, or soft scales. These do not form a shell or scale over the body nor do they lose entirely their legs and the power of changing location. They are usually less flattened, softer, and, when mature, in most cases larger than the armored scales. Certain kinds, such as the mealybugs and the fluted scale, move about from one location to another throughout their lives. Others, such as the black, soft brown, and wax scales, usually settle down when partly grown and remain in one spot, though they are able to move about even in the later stages. The males of both classes of scale insects are minute gnatlike insects with wings.

The relations of the Argentine ant with the soft scales and aphids are direct and mutually beneficial. The ant is attracted to these insects for their honeydew, a sweet liquid which it induces them to excrete by stroking their bodies with its antennæ, or feelers. The honeydew of soft scales, aphids, and some other insects forms an important part of the food of the ants. In securing this sweet excretion the ants continually surround the scales and aphids and attack any other insects that attempt to reach them. In this way they afford considerable protection to the scale pests and make it possible for certain species which have numerous and effective predacious enemies to thrive and increase to the point of causing severe infestations.

The Argentine ant does not obtain honeydew from the armored scales, but in patrolling the trees constantly in large numbers in search of insect prey it hinders to a certain extent the work of the natural enemies of these scales, and if the control of the scales is neglected for several seasons the infestation is increased considerably.

Contrary to the general belief, the ant does not itself distribute the scales and aphids of orange trees to start new colonies, although an occasional ant is seen carrying living scales or aphids, or scale shells, to the nest for flesh food and for nest construction. Of course, wherever the abundance of scale insects has become greatly increased through the presence of ants, a more rapid spread of the scales through the usual agencies, such as winds, birds, etc., naturally follows.

THE ANT AND SOFT SCALES IN CALIFORNIA.

Mealybugs.[1]—Infestations of mealybugs of the orange have been increased greatly in Los Angeles County, Cal., by the Argentine ant. In this county the orange trees usually are kept free from other scale insects and in vigorous health, and under these conditions, when protected from their numerous predatory enemies by the ants, the mealybugs are able to thrive. These natural enemies effect a practical control of the mealybugs in many Los Angeles County orange groves in the absence of the ant. As a result of the attendance of the Argentine ant, infestations of three or four species of mealybugs other than the common one are increasing in number and severity, particularly in the Pasadena district.

Fluted scale.[2]—The fluted or cottony-cushion scale is almost, if not quite, as eagerly sought and as closely attended by the Argentine ant as are the mealybugs, owing, no doubt, to the large amount of thick excretion which it supplies. At present, however, the ant can not be said to cause the slightest injury to orange trees in California through its relations with the fluted scale. Infestations of this scale become as severe at times in some localities, whether the ant is present or not, as when the insect was at the height of its abundance in earlier years. During 1916, however, the insect was very scarce, even in the worst ant-infested orchards of Los Angeles, Riverside, and Ventura Counties, there seldom being more than one or two scales per tree. The chief factor in their control in California seems to be insect enemies, chiefly the Australian lady-beetle,[1] a parasitic fly,[2] and lace-winged insects;[3] but there appears to be some other unknown factor assisting.

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[1] *Pseudococcus citri* (Risso) and other species of Pseudococcus.

[2] *Icerya purchasi* Mask.

Black scale.[4]—In California the black scale is rated as the most important of all the citrus scales. It is generally held in check by annual or biennial fumigation. Whether ants are in attendance or not, infestation by this scale often becomes very severe and capable of causing a heavy loss of crop after a single season in which fumigation has been neglected. Sometimes infestation is greater in trees where there are no ants than in others of the same age and condition overrun by ants. The black scale has quite a number of natural enemies, including one or two intermittently effective internal parasites, but these enemies do not seem capable of keeping it under control; hence interference by the ant with the work of these enemies does not accelerate greatly the increase of the scale.

Soft brown scale.[5]—The soft brown scale is a favorite of the Argentine ant. In Riverside County, Cal., this scale appears to have increased considerably in certain ant-infested groves, especially where for a long time fumigation has been neglected. Ordinarily it is controlled along with other scales by fumigation and no special treatment for the ant is needed. In Los Angeles and Ventura Counties both the soft brown scale and the closely allied citricola scale[6] are scarce in ant-invaded as well as in ant-free orchards. On more isolated ornamental trees, bordering some of the streets of Pasadena where the ants have become numerous, the scales are much more numerous than where there are no ants.

The control of scales by fumigation in California makes it improbable that the ant will increase seriously the damage from the black and soft brown scales in those orchards where fumigation is conducted regularly, although annual fumigation may become necessary in all groves invaded by the ants. The control of the mealybugs will be facilitated greatly, and in many cases accomplished fully, by the protection of the trees from ants. There are no present indications that the ants will cause the fluted scale to become again a menace to the State.

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[1] *Novius cardinalis* Muls.

[2] *Cryptochaetum monophlebi* Skuse. (Identified by Frederick Knab.)

[3] *Chrysopa califorica* Coq. and possibly others.

[4] *Saissetia oleae* (Bern.).

[5] *Coccus hesperidum* L.

[6] *Coccus citricola* Campbell.

THE ANT AND SOFT SCALES IN LOUISIANA.

Mealybugs.—The ant has not had any such decided effect in increasing the severity of mealybug infestation in the orange groves of Louisiana as in those of California. The mealybugs usually start to increase rapidly in some groves of Louisiana in the spring and early summer and threaten to infest certain of them severely. But at some time between June 15 and August 1 they are brought under control by their natural enemies, regardless of the presence of the ants. The common mealybug[1] is at present held in check in the Louisiana orange groves partly by its natural enemies, partly by the overcrowding of the trees with armored scales and white flies, and partly by the poor condition of the trees. The insect does not cause the slightest damage to the orange trees, nor does it blemish the fruit, under present conditions in Louisiana.

Fluted scale.—The fluted scale never yet has been found in the orange groves of Louisiana, except in small and isolated plantings on the Metairie Ridge. It therefore may be dismissed with the citrus mealybugs as of no present importance as a cause of injury to orange trees in Louisana.

Black scale.—Although the black scale occurs in parts of New Orleans where the ants are most numerous, the ant has not yet caused any great increase of infestation there, and this scale has not come to the front as a pest, even of the ornamentals on which it occurs. It does not appear to be present in the orange groves proper of Louisiana.

Soft brown scale.—In the Louisiana orange groves the soft brown scale appears and disappears, being kept in check mainly by its internal parasites, against which the ants are relatively ineffective. The scales form in larger groups on occasional branches of an orange tree when attended by the ants than in cases where there are no ants. Occasionally trees are found having one or more small branches heavily infested, but even where the ants are most numerous the trees are not infested to a seriously injurious extent. The largest groups of soft brown scales occur on food plants other than orange trees in Louisiana.

From the foregoing it must be recognized that under present conditions very little damage is done to the orange industry of Louisiana by the Argentine ant through its relations with the unarmored, or soft, scales. Only four of the six principal kinds of orange-infesting soft scales occurring in this State have been found in the orange groves proper. At least two of these four, namely, the Florida wax scale[2] and the barnacle scale,[3] although attended by the ants, show no likelihood of ever becoming dangerously numerous. The fluted scale may gain an entrance into the orange groves, and under ant attendance and other favorable conditions may become a serious menace. There is probably little to fear from the black scale under the climatic and other conditions which obtain in Louisiana.

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[1] *Pseudococcus citri* (Risso).

[2] *Ceroplastes floridensis* Comst.

[3] *Ceroplastes cirripediformis* Comst.

THE ANT AND ARMORED SCALES.

The armored scales do not excrete honeydew or any similar liquid attractive to ants and, contrary to the general belief, are not attended by ants. They probably would become the prey of the ants if it were not for their protective shield, or scale. Ant shelters, or "cow sheds," sometimes occur over large and small groups of the armored scales, but the number of scales covered is so exceedingly small that it is unimportant. These shelters are erected for the protection of the ants and not for the protection of the armored scales. The ant does not disseminate any of the armored scales of citrus or colonize them upon new growth or new trees.

The ants eat all insects that they can capture except those supplying honeydew, and therefore they disturb certain enemies of the armored scales, and perhaps occasionally feed on the eggs of some of them. It therefore may happen that after two or three years of heavy and constant ant attendance, an orchard that is never sprayed or fumigated for the control of the armored scales may become more heavily infested by these scales than if ants were not present. Severe and injurious scale infestations may develop in a single year, in unsprayed orchards free from ants, as the natural enemies of the scales are not effective control agents. The injury caused by these scales, therefore, can not be prevented by destroying the ants. Direct control measures against these scales must be adopted and persistently practiced if orange growing is to be made profitable.

There are four important and destructive armored scales of orange trees in Louisiana—the purple scale,[1] chaff scale,[2] long scale,[3] and white scale.[4] The purple and chaff scales are by far the most numerous, generally distributed, and injurious, and for a long time have been among the leading citrus pests of Louisiana. The infestations of the armored scales are sometimes more severe where ants occur, sometimes more so where they do not, and are almost certain to be severe in untreated groves. These scales are more numerous on the present-day budded orange trees of Louisiana than they ever were in the seedling trees which formerly were common and which still are grown in large numbers in Cameron Parish, but this is due to the greater resistance of the seedling trees to scale infestation.

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[1] *Lepidosaphes beckii* (Newm.).

[2] *Parlatoria pergandei* Comst.

[3] *Lepidosaphes gloverii* (Pack.).

[4] *Chionaspis citri* Comst.

The purple,[1] red, and yellow scales are the most important armored scales on citrus trees in California, but these usually are controlled in this State by hydrocyanic-acid gas fumigation, the results of which are not interfered with by the ants. Judging from present information the ants do not appear to cause excessive infestations of any of these scales in California.

THE ANT AND THE ORANGE APHIS.[4]

Notwithstanding the fact that the common aphis, or "green louse," infesting orange trees appears to be desired less by the Argentine ant than are the soft scales mentioned, it always is attended directly and stroked by the ant for its honeydew. This aphis, furthermore, should receive quite as much benefit as the armored scales from the mere occurrence of the ants upon the trees, but it suffers heavily from internal parasites, whereas scales do not. The ants are ineffective against these little parasites, which often may be seen "stinging" and depositing their eggs in aphids, even while attended by the ants. The parasites are very small and active and nimbly avoid the ants.

The orange aphis becomes abundant on the tender growth in the spring in both Louisiana and California, and often increases during April and May, sometimes causing some of the leaves to curl. It disappears rapidly, and numerous dried remains, each with a circular hole through which a parasite has emerged, indicate the effectiveness of these little enemies. The parasites are aided in the destruction of aphids by certain lady-beetles, lacewings, and syrphus-fly larvæ, which are more or less immune to the attack of the ants. The parasites, however, destroy a very large proportion of all the aphids, and very effectively control them in ant-infested as well as all other orange groves of California and Louisiana. The Argentine ant, therefore, does not cause any important loss to the citrus industry through the orange aphis.

THE ANT AND THE CITRUS WHITE FLY.[5]

The Argentine ant does not attend or obtain honeydew from the citrus white fly. It is a direct enemy of this insect, the adults of which it captures in large numbers during the principal emergence periods. The ant sometimes is seen with immature stages of the white fly in its jaws, but these are usually pupæ from which the adult insect is almost ready to emerge and which the ant impatiently has seized. A varying proportion of the emerging white flies are captured by the ants, and in some cases for days at a time more than half of the foraging ants will be seen carrying these insects down the trees.

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[1] *Lepidosaphes beckii* (Newm.).

[2] *Chrysomphalus aurantii* (Mask.).

[3] *Chrysomphalus citrinus* (Coq.).

[4] *Aphis gossypii* Glov.

[5] *Dialeurodes citri* (Ashm.).

The continuous patrolling of the trees by large numbers of ants must have the same disturbing effect upon predatory insects which may feed upon the white fly as upon those which prey upon the armored scales. Nevertheless, these enemies do not prevent extremely heavy white-fly infestation in orchards where there are no ants, whereas in groves in which ants are extremely numerous the amount of white-fly infestation often is small.

PREVENTION OF INJURY TO ORANGE TREES.

In Louisiana the damage resulting to the orange industry from the presence of the Argentine ant may be prevented largely by one or more of the following measures: (1) General improvement in orchard cultural practices, including the control of such orchard pests as the armored scales, the white fly, and the rust mite. (2) Direct measures for the destruction of the ant colonies and the use of ant barriers.

In California the means of preventing injury and controlling the ant are somewhat different. The armored scales are controlled by standardized methods of fumigation;[1] and other orchard practices also are standardized to some extent. Banding, as described on pages 19 and 20, to keep ants from ascending and descending the trees, and poisoning (see pp. 17–19), appear to be the most promising methods of control in that State.

BETTER ORCHARD CULTURE AS A PREVENTIVE OF INJURY IN LOUISIANA.

In Louisiana the first step toward preventing injury by the Argentine ant should be the control of the armored scales, through which most of this injury occurs, and the improvement of orchard practices in general. The destruction of the ants will not remove the necessity of controlling the armored scales and other principal pests, nor will it prevent injury due to faulty cultural conditions.

Orange growing in Louisiana never has received the care and attention that it merits, and it is capable of much greater commercial development than it has yet attained. In the earlier days citrus trees were grown there mostly for ornamental purposes or in small yard plots supplying only enough fruit for home consumption. Then followed small groves, almost exclusively of hardy seedling varieties largely resistant to insect pests, the fruit from which represented almost clear gain, no money having been expended to grow it, and the profits merely supplementing those from more important sources.

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[1] See Farmers' Bulletin 923, "Fumigation of Citrus Trees," which may be had free on application to the Division of Publications, United States Department of Agriculture.

Most of the present plantings are budded trees set out since the great freeze of 1899, which killed to the ground every orange tree in the State. These trees are much more susceptible to injury from insects and other natural influences encountered in Louisiana than are the seedling trees. The nursery stock was largely of inferior quality, and the trees usually were planted too close together in shallow, wet soil, which encourages the roots to cover a great area close to the surface. The insect pests were allowed to flourish unchecked, all cultural care was neglected, and many of the trees were damaged further by floods, storms, and freezing. As a result a large proportion of them have remained undersized and in poor health. The amount of production has never reached that of normal healthy trees, and at from 7 to 10 years of age both trees and crop began to fail. The maximum production of Louisiana orange trees was but slightly more than three-fourths of a box per bearing tree, and the present production is only about one-half of a box per tree.

The success of certain well-tended orange groves in Louisiana demonstrates that oranges can be grown with profit in the State. The only commercially successful and profitable groves, however, have been those which receive an amount of care and attention much above the average for the State. The Argentine ant now occurs in slightly more than one-fourth of the Louisiana orange groves.

Comparison of the condition of the trees and the amount of the crop in ant-invaded groves with those in groves in which there are no ants shows that only about one-sixth more of the trees of the former are in poor condition than of the latter, while the average reduction in crop is only about one-fifth greater per tree in ant-invaded groves. This difference probably is due largely to the greater neglect of ant-infested trees because of discouragement at the invasion of the ant.

There are, of course, a number of groves in Louisiana that consist of trees of such poor quality and in such a run-down condition that they will never repay the cost of reclamation. There are others, however, that can be so improved by spraying, cultivation, and pruning that the production will be more than doubled in a single season and still further increased by continued treatment.

In Louisiana, therefore, the improvement of cultural conditions and the control of the armored scales, white fly, and rust mite, the principal injurious pests, are absolutely imperative if orange growing is to be made successful, even where the Argentine ant is not present. These insects can be controlled, even with the ant present, by following a properly arranged program of spraying,[1] and they can not be controlled by the destruction of the ant alone. Presence of the ants will not interfere with the control of these pests by spraying.

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[1] For effective insecticides and directions for spraying, see Farmers' Bulletin 933, "Spraying for the Control of Insects and Mites Attacking Citrus Trees in Florida," which may be obtained free from the Division of Publications, United States Department of Agriculture.

TRAPPING THE ANT IN LOUISIANA.

In Louisiana, owing to heavy annual rainfall, the ant colonies can be collected in specially constructed traps and destroyed, a thorough control thus being effected at moderate expense. Moreover, if this method be followed diligently, permanent control, which at the same time will eliminate the ant as a household pest, will be achieved. This is by far the best and most practicable means of destroying the Argentine ant in the orange groves of Louisiana.[1] It is the only method adapted to ant destruction in large groves and can be used equally well in house lots. The trapping method of destruction is based on the fact that the ants can be induced to concentrate in populous colonies in artificial nests to avoid rain and can there be conveniently killed by fumigation. The trap box meets every nesting requirement of the ant under Louisiana conditions. Not only are rains and cold excluded, but to a large extent draughts and light also. Larger numbers of ants will mass together in numerous small colonies than in a few

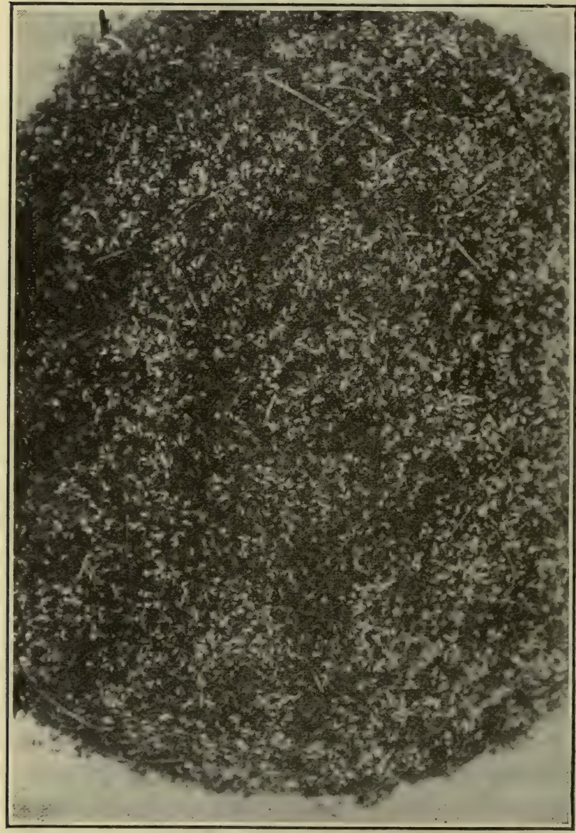

FIG. 1.—Average killing of Argentine ants in ant trap used in Louisiana orange groves.

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[1] The discovery that the ants would nest in large numbers in boxes of decaying vegetation in winter was first made by Messrs. Newell and Barber, who describe a method of destroying them based on this fact. (See U. S. Dept. Agr. Bur. Ent. Bul. 122, p. 95–96.) The trapping method described in the present bulletin depends upon the nesting of numerous small colonies, that is, colonies averaging only from 100 to 160 queens each, in a specially devised trap box which excludes rain.

extremely large ones. The traps are therefore small and a rather large number per acre are used. An average-size mass of ants killed in one of these traps is illustrated in figure 1.

CONSTRUCTION AND COST OF TRAPS AND FUMIGATING COVERS.

The trap (figs. 2 and 3, A) is made of ⅞-inch sap pine and consists of the following nine pieces:

Two sides 12 by 12 inches.
Two sides 10 by 12 inches.
One bottom 10 by 10 inches.
Two top pieces 8 by 12 inches.
Two pieces triangular molding 12 inches long.

First the smaller sides and bottom are fastened together, then the larger sides added. Rosined nails or screws should be used in order to prevent separation at the seams and resultant enlargement of the box to a size too great for the fumigation cover. The top pieces are fastened together in the form of a gable with a tight joint, this roof merely resting, loose, upon the top of the box to exclude rain. The pieces of molding are nailed across the inner sides of the roof to hold it in place.

A cover to keep the gas in while fumigating is made of 28-gauge galvanized iron, consisting of one piece 38 by 13¼ inches, bent into two right angles, forming two sides and the top, and two pieces 13¼ by 13¼ inches, forming the other two sides. The edges of the latter two pieces are folded over those of the first piece and hammered tightly together. Covers with hammered seams are suitable if very well made, but soldered seams are to be preferred, although they may be slightly more expensive. The completed cover (fig. 3, B) should measure 12½ by 12½ inches inside, after a margin of one-fourth inch has been turned down all around the edge to reinforce it.

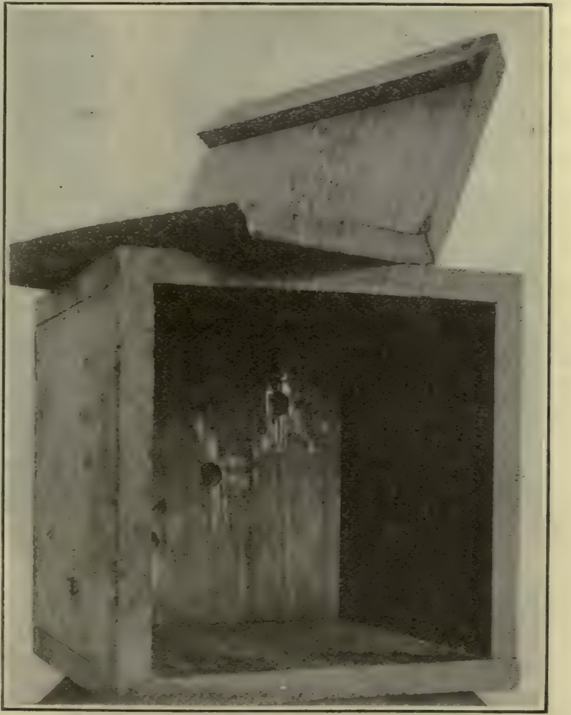

FIG. 2.—Trap used in destroying the Argentine ant in the Louisiana orange groves. (Note.—There should be only a single hole in the bottom to connect with the ant galleries under the trap.)

The cost of the traps, based on the price paid for 400 of them used in experimental work in 1914, would be about 31 cents each. The traps in question, made of C-grade sap pine, all parts cut to fit by the milling company furnishing the lumber, were supplied knocked down at 23 cents each, to which there was an additional charge of 8 cents each for transportation and setting up. The cost of the fumigating covers, based on the purchase of 48 of them in 1914, would be about 75 cents each, delivered.

PREPARING THE ORCHARD AND SETTING THE TRAPS.

The favorite rainy-weather nesting places of the ant are under loose boards, boxes, logs, sacks, and other loose pieces of cloth, and in piles of lumber or bricks, dead weeds, etc. The ants also nest in the walls of buildings when opportunity offers. They seek the higher, better drained ground in wet weather, and usually the larger colonies will be found on ditch banks and the high ground at the base of the trees.

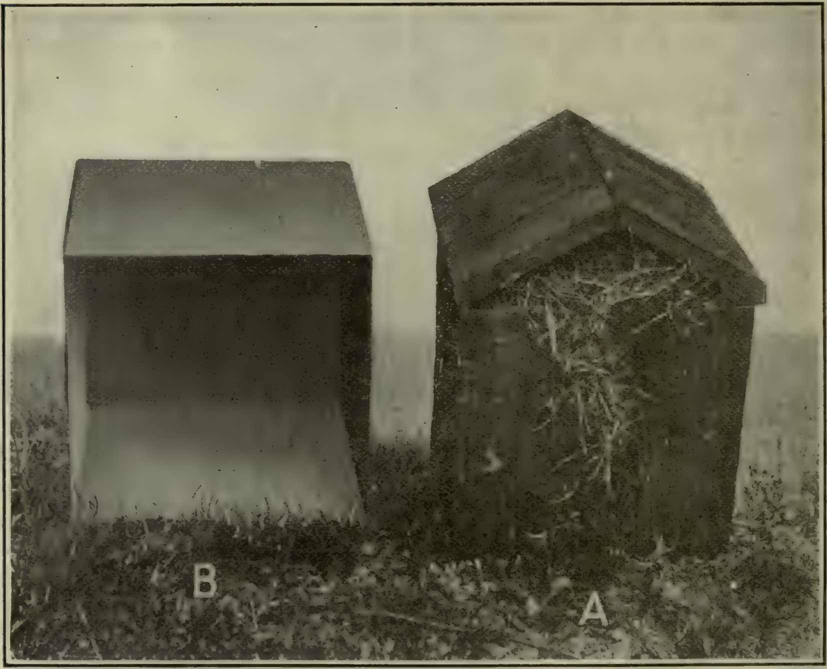

FIG. 3.—Trap (A) and gas-tight cover (B) used in destroying the Argentine ant in Louisiana orange groves.

In order to induce more rapid concentration of the ant colonies in the traps, the orchard as far as possible should be kept free from suitable natural nesting places. It should be cleared of loose boards and all similar materials under which the ants might collect. Piles of dry weeds, cowpeas, and prunings from the orange trees should not be allowed to collect in the grove, and stacks of lumber should be set upon posts banded with the adhesive recommended on page 20, to keep the ants out. The grove should be clean cultivated, from March to September, by plowing and disking both ways of the grove three or four times during that period. Even the cover crops should not be grown during the first season of trapping, or until a very large part of the ants have been destroyed.

There should be at least 25 traps to the acre of 100 trees, and the destruction of the ants will be accomplished much more rapidly if twice that many are used. If 25 are used, one trap should be placed near every other tree in each direction. For example, starting with the first orchard row, set a trap near each of the first, third, and fifth trees, etc., throughout the length of the row, then similarly in the third, fifth, and seventh rows, etc. The traps should be located just under the outer spread of the trees, where they will not be in the way of the cultivator or so close to the tree that it will be injured by the carbon disulphid gas. At a distance of about 4 feet from the trunk the trap still will be on the tree hill and there will be no danger of injury to the tree from the fumigant. The trap should be placed upon a slight, level elevation made by throwing up and smoothing off a few shovelfuls of soil.

The number of covers necessary will depend upon the number of traps and the conditions of labor. In experimental work with 415 traps, 48 covers could be operated most economically in fumigating, as a crew of three could handle this number without loss of time between setting and removing the covers. Therefore the proportion of covers may be estimated roughly at 12 per 100 traps, or 3 per acre of 25 traps, where 300 or 400 traps are used.

In winter the traps should be filled with damp but not wet stable manure and dry weeds or straw, the manure occupying the lower half of the box. In summer the manure, which is used principally for its heat, may be omitted. Maggots of the house fly, and perhaps other insects which inhabit the manure, serve as an added attraction to the ants. It is important to keep the lids always on the traps, to keep out rain and darken the nest, and to help retain its warmth in winter. As rain is by far the most important factor in driving the ants into the traps, many more ants will be destroyed by trapping in summer than in winter.

METHOD AND COST OF FUMIGATING THE TRAPS.

When the traps are full of ants and ready for fumigation the lids are removed, 2 fluid ounces of carbon disulphid poured in, and the covers slipped on and banked with soil, one shovelful being tamped down at each side to help retain the gas. The traps must be fumigated for one hour. Two ounces of carbon disulphid per trap of 1 cubic foot capacity, for one hour, kills all stages of the ants in the traps and for 3 inches in the ground beneath, as well as worms, sowbugs, etc., inhabiting the soil.

Once fumigation is started, it should be completed in 4 or 5 days, or before possible dry weather may cause the ants to leave the traps. If the number of traps is small, one man can conduct the fumigation, but where there are 300 or 400 or more traps the work can be done most efficiently by a crew of three, one to carry and measure the insecticide while the other two remove and reset the covers and bank with soil. Such a crew, working continuously, can handle 48 fumigating covers, removing them from one lot of traps and placing them over the next in from 50 minutes to one hour. Three men can fumigate over 1,000 traps in 4 days.

The same trap filler may be used indefinitely, but it and the traps must be aired thoroughly after each fumigation. The filler should be spread out on the ground and the traps turned up to the sun for several hours before resetting.

The cost of installing and operating the ant traps, based on the prices prevailing in 1914–15, would probably run about as follows, per acre of 100 trees:

25 traps at $0.31 each	$7.75
3 covers at $0.75 each	2.25
Net cost of traps and fumigating covers per acre	10.00

In practice a crew of three have fumigated 400 traps in 1½ 8-hour days; their services, at the rate of $1.25 per day each, cost $5.62. The price of carbon disulphid prevailing in 1915 was $10.75 per hundred pounds. On this basis the cost of fumigation, with the use of 25 traps per acre of 100 trees, would be about as follows:

Cost of labor, fumigating 25 traps at $0.014 each	$0.35
Cost of insecticide, 25 traps at $0.013 each	.325
Net cost of fumigation per acre	.675

From five to eight fumigations about one month apart will be necessary to reduce the ants to an inconsiderable number in the orange grove.

USE OF DRAINAGE DITCHES TO PREVENT REINFESTATION.

The orange grove will be rid of ants more rapidly if reinfestation is prevented by means of barrier ditches. This means of preventing the spread of ants is well known in Plaquemines Parish, where some of the growers have adapted drainage ditches to this use. Where drainage ditches already have been dug around three sides of the orchard, as is the case in many orchards, they need only to be cleared of weeds and provided with divided bridges which ants can not cross (figs. 4 and 5) to adapt them for use against ants. On the lower land subsurface water will remain in the ditches practically throughout the rainy weather. In higher sections it will be necessary at times to flood the ditches with water from the river by means of rice-irrigating siphons. The water can be siphoned over the levee in the high-water stage, but must be forced over with gasoline engine and pump during the low stage. The ants spread very little by flight, but will travel far in the usual trails to nest in the traps, food usually being plentiful in the orange trees near at hand.

COOPERATIVE AND COMMERCIAL TRAPPING.

By cooperative trapping, in which all the landowners in a given section club together to purchase traps and insecticide, the ants can be destroyed more thoroughly and rapidly than if each one should undertake the work on his own account. Special crews could be trained to carry on the fumigation efficiently, and the cost of the traps and insecticide would be reduced by purchasing in large quantity. The trapping method also might be put to use in southern Louisiana by commercial concerns, which could undertake to rid the land of ants at so much per acre.

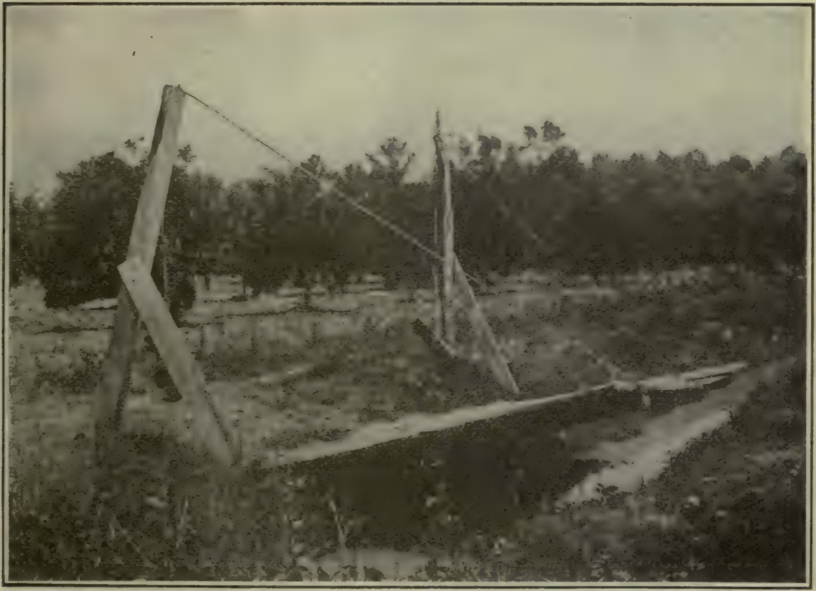

FIG. 4.—A bridge which the Argentine ant can not cross. (Newell and Barber.)

USE OF POISONED BAITS[1] AND ANT BARRIERS.

POISONING THE ANTS.

Destruction of the Argentine ant by means of poisoned sirups and other baits in orchards where orange trees, weeds, and windbreaks or borders of ornamental plants are left accessible to the ants is too slow and uncertain to be of practical value. Under such circumstances only a small proportion of the ants will be attracted from the natural sources of food in the trees and weeds, as they soon learn the injurious nature of the poison and ignore it, while continuing to feed at the usual near-by sources of supply.

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[1] For a discussion of the control of the Argentine ant in the household, the reader is referred to Bulletin No. 377 of the United States Department of Agriculture, "The Argentine Ant: Distribution and Control in the United States."

It is absolutely necessary, therefore, if satisfactory results are to be obtained by this method, that all sources of food other than the poisoned bait be eliminated so far as possible. This involves clean cultivation and the banding of all trees, orange and ornamental, with a mixture that will keep the ants out. Tree-banding alone in some cases will cause a large proportion of the ants to migrate to another locality in search of food and, as long as maintained, will have the desired effect of preventing injury to the trees from the ants.

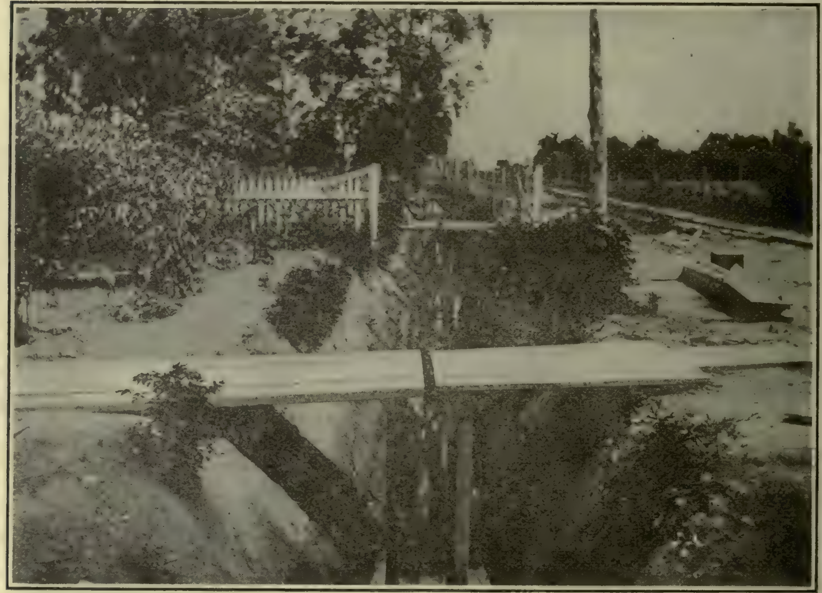

FIG. 5.—Bridges which the Argentine ants can not cross. (Newell and Barber.)

Although the employment of poisoned baits in accordance with the instructions given below often may prove practicable and effective in ridding yards where there are comparatively few trees infested by ants, this method can not be recommended for general orchard use in Louisiana as a substitute for the trapping method.

In preparation for the poisoning work, the premises should be first freed of weeds, long grass, vines, and other plants that can not be banded to keep out ants and that harbor aphids and scale insects. Then all the trees should be banded in accordance with the directions on page 19. The ant poison then should be distributed liberally about the premises, in containers that will keep out rain. One-pint fruit jars, of the type illustrated in figure 6, are suitable for this purpose. A single hole is punched in the center of the lid for the admission of the ants. A piece of sponge is placed in each jar to aid the ants in reaching the poison. Scrap or waste sponges suitable for this purpose sell for about 25 cents per pound at drug stores, and 1 pound of them will serve for a dozen or more jars. About one-half pint of sirup will serve for each jar. The jars should be laid on their sides, and occasionally shifted to a new position.

The best poison is prepared as follows: Make a sirup by stirring 8 pounds of granulated sugar in one-half gallon of cold water until dissolved, making 1½ gallons of sirup. Then add 4½ ounces of chloral hydrate crystals, previously dissolved in a small quantity of water, and about one-half pound of strained honey. The honey will add to the attractiveness of the sirup.

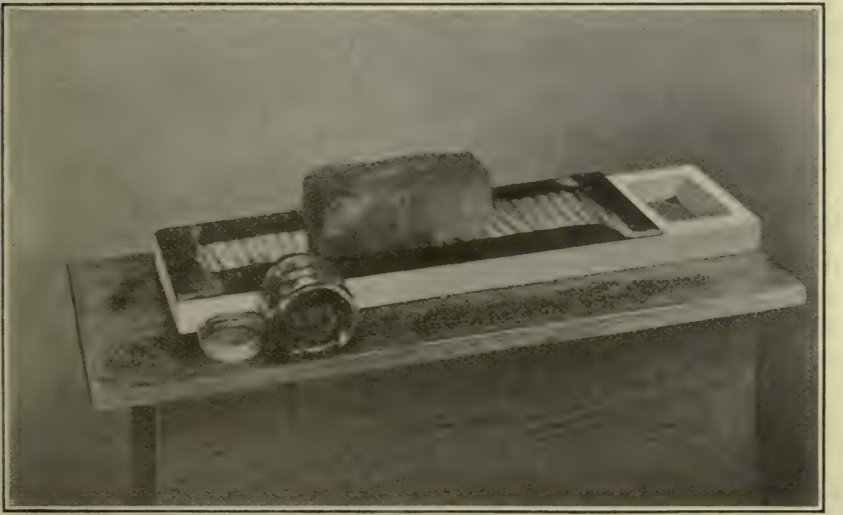

FIG. 6.—Artificial ant nest and jars used in poisoning the ants.

If chloral hydrate can not be obtained, arsenite of soda may be substituted. Dissolve 62 grains of tartaric acid crystals in 3½ pints of water. Then add 8 pounds of granulated sugar and boil until dissolved. Allow to cool. Dissolve about 200 grains of arsenite of soda (or 172 grains of white arsenic) in one-half pint of hot water. When cool add to the sirup. Then add from one-half to three-fourths pound of strained honey. The tartaric acid prevents the souring of the arsenical sirup, which the ants will take very slowly.

USE OF TREE-BANDING MIXTURES.

In Louisiana orange groves the extensive use of adhesive and other repellent mixtures for banding tree trunks to keep out ants is not recommended in view of the more positive method of destroying the ants by trapping. When used on a large scale, even the best bands of this sort will need more or less frequent inspection and renewal or respreading. Although the first cost of banding possibly might be less than that of installing traps, the cost of permanent maintenance would exceed the cost of trapping, and under present conditions would not be justified by the increased crop returns. Tree banding would cost more in Louisiana than in California, as in most cases an average of three bands would be required for every orange tree banded in Louisiana, owing to the growth habit of the trees. Furthermore, such barriers do not reduce the ant population, and therefore can not be considered a positive means of control. In Louisiana, therefore, the chief use of these mixtures will be found in protecting yard trees and beehives from the ant and in keeping it out of food supplies, beds, etc., in the house.

The most effective adhesive type of banding mixture, determined from much testing of various materials and combinations of them, is composed of 1 part by weight of flowers of sulphur to 6 parts of commercial tree adhesive. All the lumps in the sulphur should be broken and the two ingredients mixed thoroughly together without heating, a wooden paddle serving this purpose. The sulphur not only keeps the adhesive soft, but also has a sufficiently repellent effect upon the ants to prevent their bridging the bands with bits of trash or their own bodies.

Bands of this material will remain effective in rainy, foggy, or exceptionally dry weather for from three to five months, and in the cool weather of fall and winter as long as the ants are able to forage out of doors. If directly exposed to the sun for long periods, however, the surface of the bands becomes hard enough for the ants to cross. The bands, therefore, must be applied where the shade of the tree will protect them. The trees must be pruned so that branches will not touch the ground, and weeds must be prevented from touching the tree above the bands and allowing the ants to cross. The mixture should not be applied directly to the bark, as it would be absorbed to some extent and in time might injure the tree. First the trunk should be wrapped snugly with tire or hose-mending tape for a space about 6 inches wide, and then the adhesive should be applied over this in a band about 4 inches wide and one-fourth inch thick.

APRIL, 1918 CIRCULAR No. 66

AGRICULTURAL EXPERIMENT STATION

KANSAS STATE AGRICULTURAL COLLEGE

DEPARTMENT OF ENTOMOLOGY

Spraying Fruit Trees

J. H. MERRILL

Fruit trees are sprayed for two reasons—to control plant diseases and to prevent damage from insects. So infrequently, however, trees suffer from one type of injury alone that most of the sprays in actual use are combined from fungicides and insecticides.

The fungicides most commonly employed are bordeaux mixture and some forms of the lime-sulphur compounds. Bordeaux mixture is decidedly the most efficient of all the fungicides, but since its use during rainy weather is almost certain to cause injury to both fruit and foliage, the lime-sulphur sprays are often substituted. There are many diseases, however, such as apple blotch and bitter rot, which cannot be controlled by lime-sulphur, while in hot weather bordeaux mixture is much safer. Hence the most satisfactory spraying method involves the use of the lime-sulphur compounds in the early season, when they are absolutely safe and will control any disease that may appear at that time, while the bordeaux mixture is applied later, when it is safer on account of the heat and most effective for the later appearing diseases.

THE LIME-SULPHUR SPRAYS

The lime-sulphur sprays may be prepared at home or some of the commercial brands may be used. Unless the grower has a large number of trees to be sprayed, it will not pay him to make the home-made solution, as the cost of securing the equipment and of purchasing the ingredients in small quantities would be prohibitive. Not only is the task of preparation very disagreeable, but unless directions are most carefully followed, failure will probably result. Since the commercial sprays are made in large quantities and with improved equipment, it is possible to produce a more uniform solution than the home-made product. However, by carefully following directions one may prepare a very satisfactory spray, which can be made during spare time and stored away for future use. The home-made concentrate has the following ingredients:

Stone lime	40 pounds
Sulphur	80 pounds
Water	50 gallons

The lime used in making this concentrate should be the purest obtainable and as free as possible from magnesium. The sulphur should also be pure and finely ground. The ordinary ground brimstone is the cheapest form but is not as satisfactory as either the flour or flowers of sulphur. The solution may be cooked with steam in barrels or in a kettle over fire. In slaking, hot water should be used, if possible. Water should be added to prevent burning, but not in such quantities as to check the slaking. After the lime is thoroughly slaked the sulphur should be sifted into the paste and mixed with it.

The solution should be diluted to 50 gallons and this amount kept constant during the operation. This may be controlled easily by notching a stick at the level of the solution when the water is first added. If steam is used for cooking, water need not be supplied, but over a fire one must watch the amount of liquid closely. The mixture must be stirred constantly to prevent caking on the sides and bottom of the kettle. The boiling should continue steadily until the sulphur is all dissolved. This usually requires from 45 minutes to 1 hour, according to the amount of heat used.

When the boiling is completed the concentrate should be strained and stored for future use in air-tight barrels. It is frequently convenient to cover the surface with oils, such as the miscible oils, since they prevent drying, will not injure the trees, and will not ignite at the temperature of boiling water.

Before being used as a spray, the concentrate should be diluted. In order to dilute the mixture properly one should use a Beaumé hydrometer, which may be obtained from any lens company, such as the Bausch & Lomb Optical Company, Rochester, N. Y., or the Spencer Lens Company, Buffalo, N. Y. Directions for using these hydrometers usually accompany them. By comparing the Baumé reading with Table I the proper amount of dilution may be determined. This table is applicable for Kansas conditions and should be used rather than the tables sent out by the companies, which, while perfectly accurate in their make-up, are prepared on the basis of 1¼ gallon of lime-sulphur solution instead 1½ gallon, to every 50 gallons of water, as a summer spray.

TABLE I.—*Lime-sulphur sprays*

Beaume reading of concentrated lime-sulphur solution	To make 50 gallons summer spray		To make 50 gallons dormant spray	
	Number gallohs concentrated lime-sulphur	Number gallons water	Number gallons concentrated lime-sulphur	Number gallons water
35	1.3	48.7	5.1	44.9
34	1.4	48.6	5.3	44.7
33	1.5	48.5	5.5	44.5
32	1.5	48.5	5.8	44.2
31	1.6	48.4	6.0	44.0
30	1.7	48.3	6.4	43.6
29	1.8	48.2	6.7	43.3
28	1.9	48.1	7.1	42.9
27	2.0	48.0	7.4	42.6
26	2.1	47.9	7.9	42.1
25	2.2	47.8	8.4	41.6
24	2.4	47.6	8.9	41.1
23	2.5	47.5	9.5	40.5
22	2.7	47.3	10.2	39.8
21	2.8	47.2	11.0	39.0
20	3.1	46.9	11.7	38.3
19	3.4	46.6	12.5	37.5
18	3.6	46.4	13.3	36.7
17	3.8	46.2	14.2	35.8
16	4.1	45.9	15.3	34.7
15	4.4	45.6	16.5	33.5

SELF-BOILED LIME-SULPHUR

Stone lime	eight pounds
Sulphur	eight pounds
Water	fifty gallons

Self-boiled lime-sulphur is a mild form of the lime-sulphur solution, a mechanical mixture of the sulphur and slaked lime. It can be used as a summer spray on stone fruits where it would be dangerous to use bordeaux mixture. Lime for this solution should be good, fresh stone lime. Under no conditions should air-slaked lime be used, as the heat generated by the slaking is all that is used in cooking the sulphur. The lime should be placed in the bottom of a barrel and enough water added to start slaking. The sulphur should then be rubbed through a sieve onto the lime and the whole stirred to prevent it from burning. Water should be added from time to time to continue the slaking process, care being taken not to add enough water to "drown" the lime. After slaking has ceased, the barrel should be covered to conserve the heat for about 15 minutes, then enough water should be added to dilute to 50 gallons. The spray is then ready for use and should be strained into the spray tank. While this is a good spray to use on stone fruits it does not seem to control apple diseases as well as the more concentrated forms or bordeaux mixture.

DRY LIME-SULPHUR

There are several forms of powdered or dry sulphur compounds that are now appearing on the market but these as yet have not been tested thoroughly enough for Kansas conditions to warrant recommending them. However, if they will do what is claimed for them they will effect a considerable saving to the fruit grower, as he will no longer be obliged to pay freight on water.

BORDEAUX MIXTURE

Copper sulphate	3 pounds
Stone lime	4 pounds
Water	50 gallons

If only 50 gallons of bordeaux mixture are to be made, 3 pounds of copper sulphate should be dissolved in 25 gallons of water in one barrel, and 4 pounds of lime in a like amount of water in another barrel. The two solutions should be kept separate until ready for use when they should be poured simultaneously into the spray tank.

If any great amount of bordeaux mixture is to be made, it will greatly facilitate the work to prepare stock solutions in advance. This may easily be done by dissolving the copper sulphate and the lime in separate barrels in known quantities of water, for example, 2 pounds of the copper sulphate or lime to each gallon of water. This will make it easy to compute the amount of lime or copper sulphate to be used in the preparation of the spray. The copper sulphate, being much heavier than water, will not thoroughly dissolve unless it is suspended at the surface of the water. A good method of doing this is to put it in a bag and fasten the bag to a stick placed across the top of the barrel. In slaking the lime, the water should not be added too rapidly as there is danger of "drowning" it and thus checking the slaking.

The most satisfactory way of preparing bordeaux mixture is to have an elevated platform higher than the spraying machine, on which are placed two tanks, each holding a little more than one-half the capacity of the spray tank. If it is not feasible to get two tanks, four 50-gallon barrels may be used, two of which will be for the lime and the other two for the copper sulphate. The two tanks should be so connected that the contents of both will flow into a common pipe and from that into the spray tank. The solution from the lime barrels should flow into one pipe and the solution from the copper sulphate barrels into another pipe. The two pipes should then be connected with a common pipe which leads to the sprayer. The purpose of this connection is to have the diluted lime and diluted copper sulphate solutions flow into the sprayer as one stream. The stock solutions should never be brought together before dilution because a chemical combination results which is dangerous to the fruit and the foliage.

If stock solutions each contain 2 pounds of material to 1 gallon of water and it is desired to make 250 gallons of spray, 7½ gallons of the copper sulphate stock may be placed in one of the tanks and diluted to 125 gallons; and 10 gallons of the lime stock, after stirring well, may be placed in the other tank and diluted to the same amount. These two solutions should be well stirred and then the valves opened so that the two streams will flow into the spray tank at the same time. This material should be strained through a 20 to 40 mesh strainer. Poison may now be added and the material is ready to be applied to the tree.

The spray to be used depends upon the nature of the insect or plant disease to be controlled and upon the weather conditions which prevail at the time of spraying. If the insect has sucking mouth parts, such as plant lice and San José scale, a "contact spray" must be used, but if the insect has biting mouth parts, such as the codling moth and curculio, an arsenical spray should be used. The contact sprays most commonly used are the lime-sulphur solution, the miscible oils, kerosene emulsion, whale-oil soap, and some of the nicotine sprays, while the stomach poisons commonly used are arsenate of lead and paris green. While paris green has the higher percent of arsenic and consequently the greater killing powers, it is not as safe to use on fruit trees as arsenate of lead and does not adhere to the leaves as well.

Arsenate of lead is now manufactured in two forms—the paste, which contains 50 percent of water, and the powdered or dry, which is practically free from water. If the powdered form is used, only one-half the quantity by weight is required. The powdered arsenate mixes a little easier than the paste, has just as good killing powers, and has the advantage of keeping over winter without danger of leaking or freezing.

DORMANT SPRAY

The dormant or winter spray is used similarly on all fruit trees, but the summer sprays differ somewhat according to the kind of trees that are being treated. The dormant spray is usually applied to control the San José scale, but if lime-sulphur is used it is equally valuable in controlling peach-leaf curl and blister mite. Because of the fact that the miscible oils will spread to a certain extent some prefer to use them rather than the lime-sulphur, but the constant soaking of the oil around the roots of the trees has an injurious effect upon them. Since the oils do not have any fungicidal qualities they cannot control the peach-leaf curl or any other plant diseases as does the lime-sulphur. In applying this dormant spray it is essential that the whole tree be covered with the spray because this is a contact spray and must hit the insect in order to kill it. If the home-made concentrate is used, it should be diluted according to the table previously given, while if the commercially prepared solution is used and the material is fresh, it should be used in the proportion of 1 gallon of the solution to every 8 or 9 gallons of water.

Since the summer sprays will vary according to the variety of the tree, the spraying of the different fruits will be considered separately.

The third, fourth, and fifth summer sprays should be applied at intervals of 10 days, using the same materials as above. As these treatments are designed to control the curculio, the fungicide may be omitted from the last two sprays if the foliage is free from any signs of disease.

Correction: This last paragraph
should supplement Table V

TABLE II.—*Spray schedule for apple trees*

When to spray	What to spray for	What to spray with	Remarks
When trees are dormant	Aphid eggs, San Jose scale	Lime-sulphur at dormant strength	Also valuable as a fungicide, and to clear up shaggy bark
When the buds are swelling and before the blossoms open	Curculio, cankerworms, tent caterpillar, apple scab, and rust	2 pounds of paste arsenate of lead or one pound of the powdered arsenate of lead and 1½ gallon of lime-sulphur at 33° Beaume to every 50 gallons of water	If aphids are present they can be controlled by adding nicotine sulphate to this spray
When the petals are one-half to two-thirds off the tree	Codling moth, curculio, cankerworm, tent caterpillar, cedar rust, and scab	Same as above	The object of this spray should be to fill every calyx cup with poison before it closes. A very important spray and one which should be applied thoroughly
Three weeks after the blossom-fall spray	Above-named pests and apple blotch*	Arsenate of lead as above but 3-4-50 bordeaux should be substituted in place of the lime-sulphur	The blotch spores are liberated at about this time and the codling moth eggs begin to hatch. As the larvæ take their first meal from the leaves, it is well to have them well coated with poison
Five weeks after the blossom-fall spray	Apple blotch	Bordeaux	If blotch is bad it will be well to apply this spray to get complete control
Ten weeks after the blossom-fall spray	Mainly for the second brood of codling moth, also to control blotch and bitter rot	Arsenate of lead as above and 3-4-50 bordeaux	If neither blotch is present nor bitter rot expected, the bordeaux may be omitted
When the fruit is beginning to ripen	Third brood of codling moth	2 pounds of arsenate of lead to every 50 gallons of water used	An immense amount of codling moth damage has appeared late in the season. This has been caused either by a third brood or by late stragglers from the second

*Better blotch control will be secured if this spray is applied about 15 days after blossom-fall.

TABLE III.—*Spray schedule for pear trees*

When to spray	What to spray for	What to spray with	Remarks
When trees are dormant	Aphid eggs, San Jose scale, and blister mite	Same as for apple	
Petal-fall	Codling moth, curculio, and scab	Same as for apple	
Three weeks after the petals fall	Same as above	Same as above	The pear is not as susceptible to insect injury as the apple and does not need as many sprays
When slugs appear	Pear slugs	Either dust or liquid arsenic spray. Arsenate of lead at the rate of 1 pound to 50 gallons of water will control this insect	

TABLE IV.—*Spray schedule for peach trees*

When to spray	What to spray for	What to spray with	Remarks
When trees are dormant	San Jose scale, peach-leaf curl, brown rot	Winter strength of lime-sulphur	If scale is not present this spray is valuable enough to justify its application
When most of the shucks have fallen	Curculio and brown rot	Arsenate of lead, 2 pounds of paste or 1 pound of dry to 50 gallons of water and self-boiled lime-sulphur	Brown rot injury follows curculio damage. It is not safe to use bordeaux or concentrated lime-sulphur on peaches
Two to four weeks after the shucks have fallen	Curculio, brown rot, and scab	Same as above	
About a month before the fruit ripens	Brown rot and scab	Self-boiled lime sulphur	

TABLE V.—*Spray schedule for cherry and plum trees*

When to spray	What to spray for	What to spray with	Remarks
When trees are dormant	San Jose scale and cherry scale	Lime-sulphur as for apples	Plums and sweet cherries may have San Jose scale, while sour cherries have cherry scale
When leaf buds begin to open (First summer spray)	Curculio	Arsenate of lead, 3 pounds of paste or 1½ of powdered to 50 gallons of water and self-boiled lime-sulphur	If plant lice are present, nicotine sulphate may be used
At petal-fall (Second summer spray)	Curculio and fungous diseases	Same as above	

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